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DETACHMENT OF THE RETINA AND ITS SURGICAL THERAPY

AN EXPERIMENTAL STUDY *

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With the advent, in 1927, of Gonin's [1] report on a procedure for the cure of detached retina, interest in this subject was stimulated anew. Numerous reports of cases in which treatment was given have appeared in the literature, and at times some inference was made as to the etiology of the condition. Because of the time element and the rarity of cases, little has been written on biopsy or autopsy material. Exactly what occurs when a detached retina is treated has not been thoroughly studied.

With these thoughts in mind, I began this study two years ago at Northwestern University. This must be considered a preliminary report, as the investigation is still being carried on, and the results are not conclusive.

The initial problem was to produce detachment of the retina in animals.

That this was not an original idea is attested by the extensive work of Weekers.[2] Because experimental detachment of the retina is necessary in a study of this sort, a review of the methods and attempts at its production does not seem out of place. In 1875, Chodin [3] showed that a loss of vitreous due to an incision into the sclera was often accompanied by detachment of the retina. Rählmann,[4] in 1876, and Leber,[5] in 1886, produced retinal detachment by carefully introducing a foreign body into the vitreous, or by merely injecting a concentrated solution of sodium chloride. Both Boucheron,[6] in 1883, and Simi,[7] in

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1. Gonin: Ann. d'ocul. **164**:817, 1927.
2. Weekers: Arch. d'opht. **42**:321, 1925.
3. Chodin: Centralbl. f. d. med. Wissensch. **13**:68, 1875.
4. Rählmann: Arch. f. Ophth. **22**:233, 1876.
5. Leber: Ber. ü. d. XIV versamb. d. ophth. Gesellsch., 1886, p. 18.
6. Boucheron: Bull. Soc. franç. d'opht. **2**:59, 1884.
7. Simi: Boll. d'ocul. **7**:39, 1884.

1884, used a dilute solution of cantharides which was injected between the sclera and the choroid. In 1895, Bach [8] resorted to an intra-ocular injection of sublimate to produce detachment in a rabbit's eye. Wessely,[9] in 1904, applied a capsule to the eyeball and caused a circular area of steam to be introduced into the collar of the capsule. Best,[10] in 1906, injected phlorhizin to effect an experimental diabetes. An exudative detachment of the retina was noted between the choroid and retina. During the twenty years following, little, if any, material on experimentation was published in this field. While studying ophthalmotonus experimentally in rabbits, Weekers [11] found detachment of the retina as a byproduct, which eventually became more fascinating than his original investigation. By using the red heat of the cautery on the exposed sclera of the rabbit's eye, he was able to produce an immediate detachment which persisted in some cases as long as five months. However, few tears or holes were found in the retina in his animals. In a recent discussion of a paper by Parker,[12] Laird [13] referred to the experimental work of Sinclair. This was also mentioned in Ball's [14] textbook, but no references were given, and I was at a loss to find any mention of it in a thorough review of the literature. Gonin and the workers who have adhered to his views, especially Vogt [15] and Lindner,[16] insisted on the necessity of a hole or tear in the retina, and emphasized the fact that cure is possible only on localization and cauterization of this dehiscence.

Speculation as to the pathogenesis of detachment of the retina has brought forth many theories. A thorough review of these theories may be found in the recent book of Anderson [17] on detachment of the retina.

In spite of the fact that Weekers had devised a method for the production of experimental detachment of the retina that in his hands gave excellent results, my associates and I felt that since the hole or tear had become the primary "bone of contention," a method that would include this was necessary. After many trials we were able to develop a technic that satisfied our need for an artificially detached retina.

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8. Bach: Arch. f. Ophth. **41**:62, 1895.

9. Wessely: Ophth. Klin. **7-8**:265, 1903-1904.

10. Best: Klin. Monatsbl. f. Augenh. **42**:538, 1904.

11. Weekers: Arch. d'opht. **43**:25, 1924.

12. Parker: J. Michigan M. Soc. **30**:61, 1931.

13. Laird: J. Michigan M. Soc. **30**:63, 1931.

14. Ball, J. M.: Modern Ophthalmology, ed. 6, Philadelphia, F. A. Davis Company, 1927, vol. 2, p. 840.

15. Vogt: Klin. Monatsbl. f. Augenh. **82**:619, 1929.

16. Lindner: Wien. klin. Wchnschr. **43**:225, 1930.

17. Anderson: Detachment of the Retina, Cambridge, England, University Press, 1931.

Reports in the literature on pathologic examination of operative detachments are indeed meager. Weekers' description of his experimentally produced detachment in a rabbit's eye is most interesting:

> In a typical picture of minimum cauterization, the episclera is moderately edematous and infiltrated, the sclera at the same time shows no manifest lesion. The choroid to the contrary is profoundly altered. It is the site of an enormous vascular congestion. The tumefaction of the choroid is seen making it appear as an erectile tissue. Intense congestion is found in the large vessel layer. An exudate is accumulated between the pigment layer and the retina.

Amsler [18] demonstrated the pathologic process in a case complicated by intra-ocular hemorrhage following the use of the cautery for a detached retina, but to my mind this complication certainly influenced the picture, and thus the interesting findings are of little value.

The first attempt to study experimentally the effect of the cautery on the eye was recorded in the very recent preliminary report of Luntz,[19] from Lindner's clinic. He was interested in knowing whether the white or the red heat of the cautery was more satisfactory. Retinas of rabbits exposed to the cautery for from two to twenty seconds were removed after from five to twenty-two days and studied. Luntz felt that it was of importance to note that tissues not in the immediate vicinity were affected by the cautery, in spite of Wessely's [20] comment to the contrary. In the discussion of this report Lindner [21] brought out the point that dire effects may be toxic in nature, and are found especially when the cautery is used for longer periods.

Of more recent publication is Guist's [22] article on his new operation with the potassium hydroxide stick. Sections showing the pathologic condition resulting after one second, which Guist found to be the optimum time, accompany the article. Lindner [21] felt that this new method, because of its chemical nature, approximating the method of Sourdille with oxycyanide of mercury, does less harm to the tissues than the cautery. A pathologic study of Guist's sections would seem to bear out this statement.

After many attempts with varying procedures, the simple technic for producing a mechanical detachment of the retina may be described as follows: The rabbit is placed under ether anesthesia, and the usual operative methods to prevent infection are carried out. The eyeball is rotated upward as far as possible, and the conjunctiva is incised down to the sclera. An incision, from 1.5 to 2 mm., is made with a cataract

18. Amsler: Ann. d'ocul. **166**:871, 1929.
19. Luntz: Ztschr. f. Augenh. **73**:380 (March) 1931.
20. Wessely, cited by Luntz (footnote 19).
21. Lindner: Ztschr. f. Augenh. **73**:389, 1931.
22. Guist: Ztschr. f. Augenh. **74**:232 (June) 1931.

knife through the sclera, choroid and retina, so that the vitreous is not entered, or at least is little disturbed. A small thin spatula about 1 mm. wide is inserted between the retinal and the choroidal coats, and by a backward sweeping motion the layers are separated. A small amount of vitreous usually escapes. No attempt is made to close the scleral opening, as this is the permanent hole that reaches through into the vitreous. The conjunctiva is closed with silk sutures; atropine and 2 per cent mercurochrome-220 soluble are instilled, and no dressing is applied. The entire procedure may be checked with the ophthalmoscope.

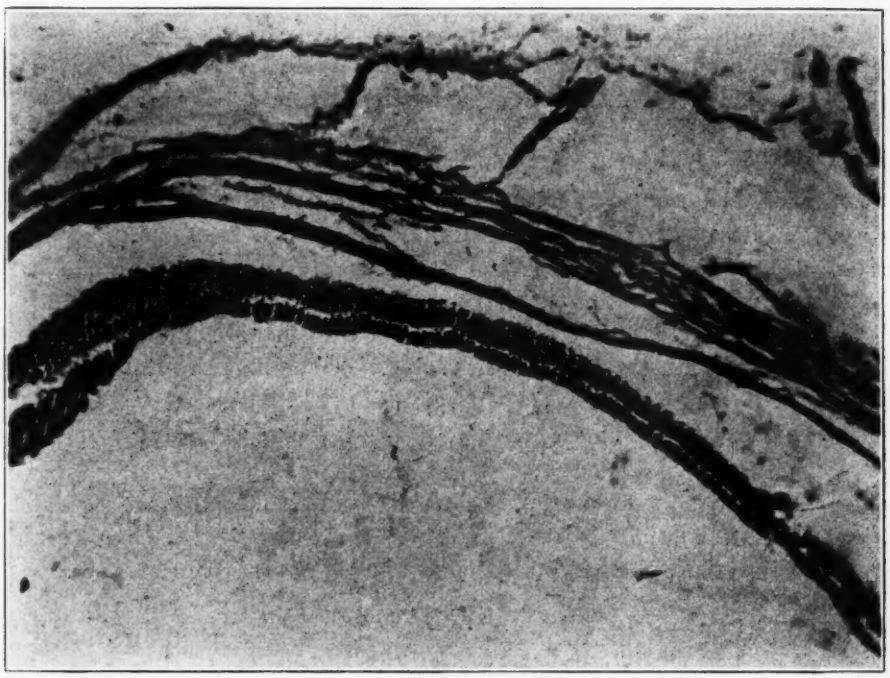

Fig. 1.—Normal rabbit's eye.

As was stated previously, many attempts have made this method the one of choice, and an explanation of why this method was accepted would simply be presuming on the time and patience of the reader. Suffice it to say that ether caused least loss of animals, mercurochrome prevented the loss of eyes by infection, and drawing off vitreous previous to opening the chamber did not enhance the ultimate results.

In order that a comprehensive understanding of the changes produced by various operative procedures may be better obtained, my co-workers and I have used various methods of cauterization, both on normal rabbits' eyes and on those in which an artificial detachment was made. The expense of making photomicrographs of serial sections

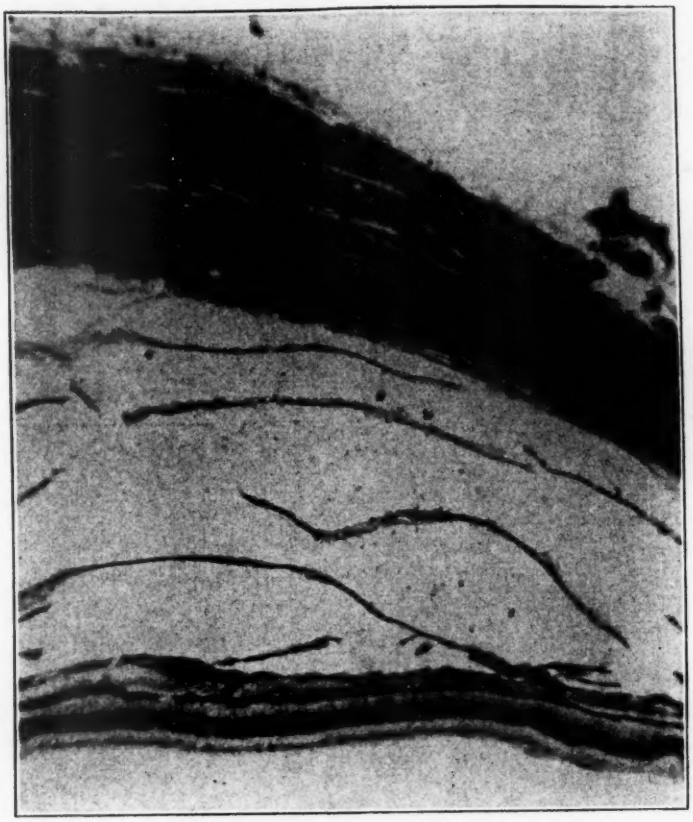

Fig. 2.—Retina artificially detached.

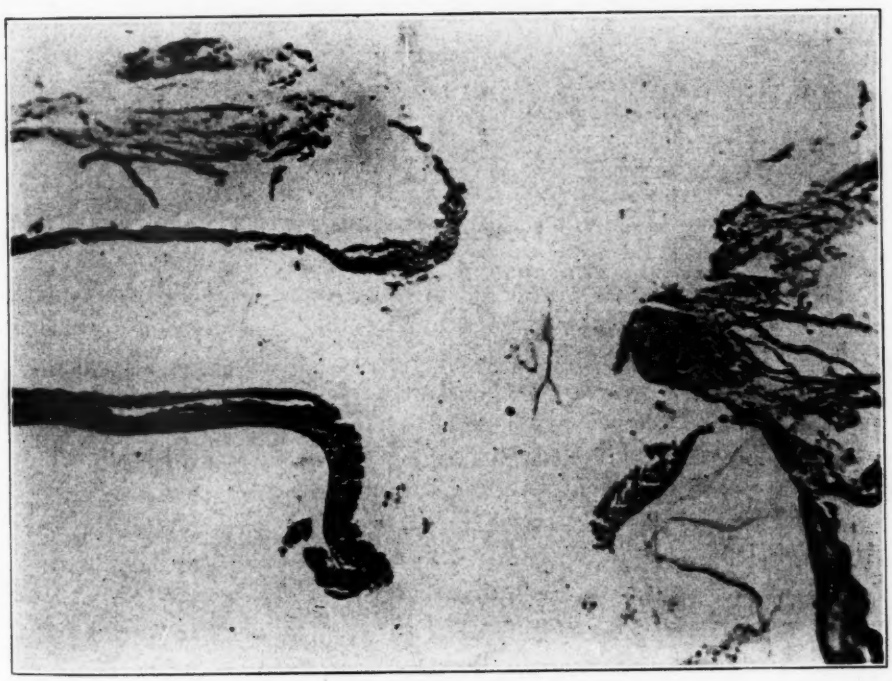

Fig. 3.—Actual cautery; normal eye.

has limited me to reproducing a few fields showing the affected area. Figure 1 demonstrates the usual picture of a normal rabbit's eye as seen under the microscope. The artefacts produced by paraffin embedding, employed for more rapid observation of the results, are shown. The pigment layer is slightly separated from the remainder of the retina on one side, and also from the choroid on the other side. Figure 2 shows the artificially detached retina. The retinal layers have been removed in toto from the choroid, and the large intervening space is filled with fibrils of choroidal tissue. A difference in the picture from what is seen

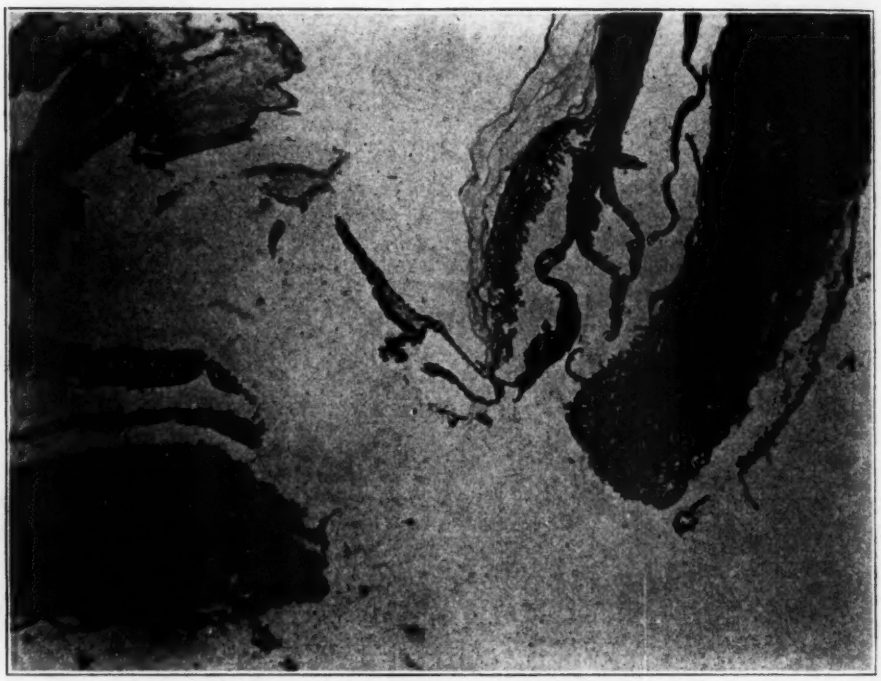

Fig. 4.—Paquelin cautery; normal eye.

in typical cases of retinal detachment is that here the layer of pigment epithelium remains adherent to the inner retinal layers and is separated from the choroid.

After the use of the actual cautery in the normal eye for five seconds, if the eye is removed before healing takes place, a large hole involving all the ocular coats, as seen in figure 3, is evidenced. This same gap is produced with the Paquelin cautery, the method of Gonin, as shown in figure 4. That such a destruction of tissue also takes place with Guist's new method is attested by figure 5, in which the potassium hydroxide stick was used for three seconds and healing was not allowed to terminate before enucleation.

Fig. 5.—Potassium hydroxide stick; three seconds; normal eye.

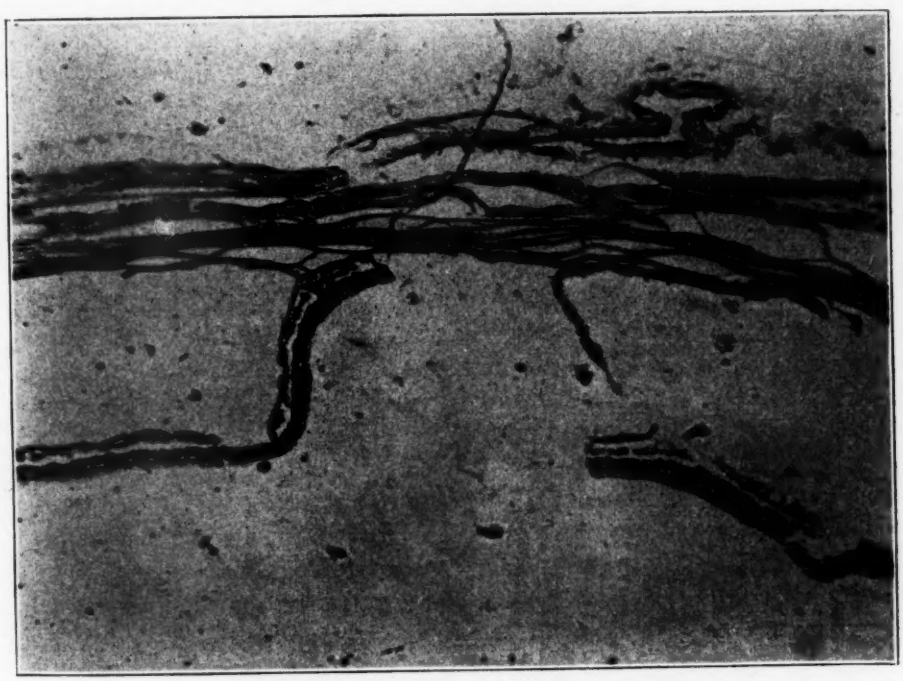

Fig. 6.—Diathermy needle; three seconds; normal eye.

With the diathermy ball,[23] the diathermy needle and Sourdille's injection of cyanide of mercury,[24] no such destruction of tissue was noted, the pathologic process consisting essentially of a pouring out of exudate between the layers. This was most noticeable when the diathermy needle was used, and least noticeable after the use of cyanide of mercury. Figure 6 shows the typical change produced by this type of procedure.

The effect of therapeutic methods on artificially detached retinas in which healing is allowed to terminate is well demonstrated to be due

Fig. 7.—Paquelin cautery in artificially detached retina.

to the pouring out of exudate which glues the retina again to the choroid. In figure 7 the hole made by the Paquelin cautery has begun to heal, and it is noted that the retinal layers, which were previously separated from the choroid, are now adherent to it in the scar tissue. That the diathermy needle also pins down the retina in the region of the inserted needle is attested by figure 8; the hole made by the needle is closed over, and the retina is seen lying firmly adherent to the edges of this hole. The granulating trephine opening is seen in figure 9, together with the plastering down of the retina on the edge of this cup.

23. Larsson: Acta ophth. **8**:172, 1930.

24. Sourdille: Bull. Soc. d'opht. de Paris, Feb., 1929, p. 108.

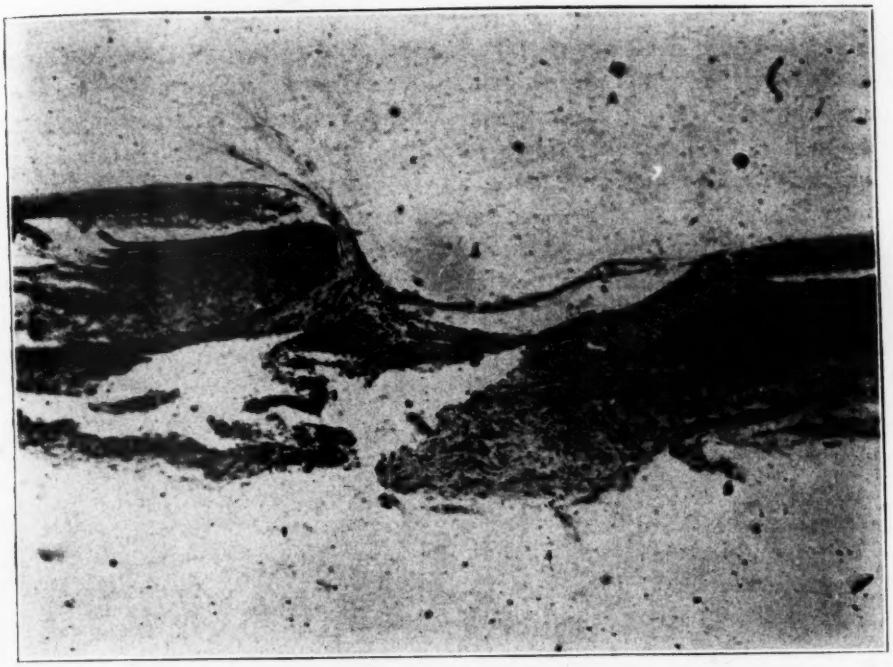

Fig. 8.—Diathermy needle in artificially detached retina.

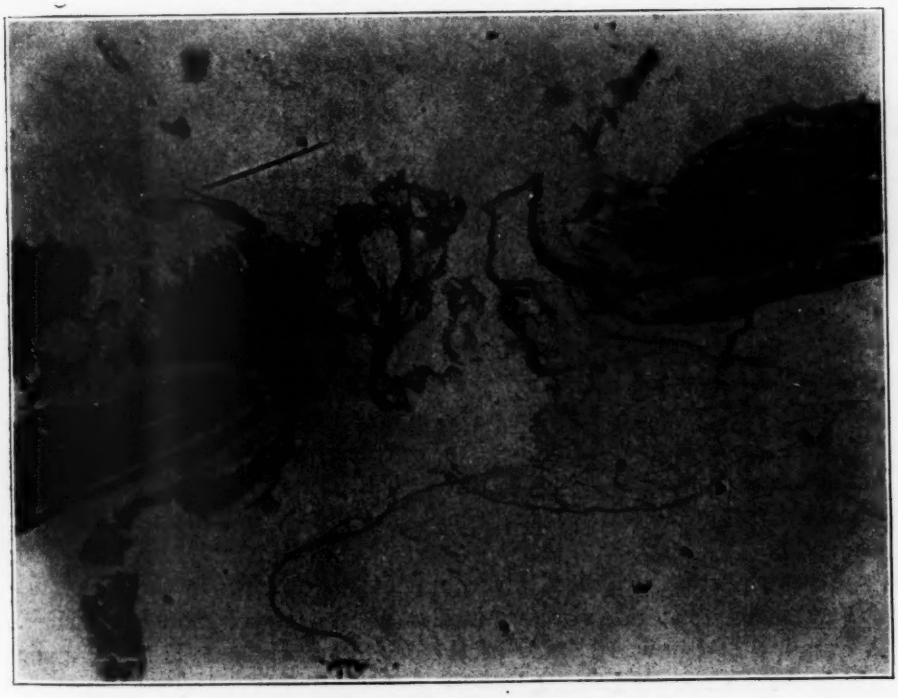

Fig. 9.—Sourdille's method in artificially detached retina.

The procedure used was that of Sourdille. A picture of the continuous layer of the retina being pinioned down is seen in figure 10; the new method of Guist was used, the stick being applied for only one second. Here it would seem that through and through destruction of the layers of the globe did not take place, as the reattached retina lies like a lid over the surface of the destroyed sclera and choroid.

In a study of the sections in toto, the striking feature was the absence or slightness of inflammatory change, which agrees with the postoperative clinical findings after the Gonin procedure.

Fig. 10.—Potassium hydroxide stick; one second in artificially detached retina.

That spontaneous reattachment might occur even without therapy was not disregarded. However, while these cases were watched ophthalmoscopically over long periods, no reattachment occurred within the first three weeks, and operative methods were attempted so that actual healing was ended before this period. Spontaneous reattachment occurred in all cases after six weeks in spite of a remaining hole in the retina.

I have purposely limited my comments to changes in the layers of the eyeball. That the vitreous is also altered is common knowledge. A chemical and physical study of these vitreous changes is being made which will be reported on later.

IMPRESSIONS

1. From this study it would seem rational to deduce the fact that the retinal tear or hole is not the entire factor in maintaining a detached retina.

2. Although reattachment occurs when the cautery is used, there is marked destruction of tissue in the vicinity of the operative wound.

3. Permanent experimental detachment of the retina has not been produced, and further progress in a study of this kind must await such a procedure.

4. Methods that do not cause this extensive destruction, but, at the same time, produce an exudate that seals the retina to the choroid would seem to be those of preference.

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ANGIOMATOSIS RETINAE WITH CEREBELLAR CYST (LINDAU'S DISEASE) *

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Since Lindau [1] correlated the syndrome of hemangiomas of the cerebellum and retina (1926-1927), and Cushing and Bailey [2] so recently reviewed the literature in reporting their case (1928), to include a review here seems unnecessary.

That the association of angioma of the retina with angiomatous and cystic lesions in other parts of the body, particularly with a cerebellar cyst, and its familial tendency are not generally recognized by ophthalmologists is evident from the statement of Cushing and Bailey [2] that "out of many examinations during the patient's life by at least eight observers, the presence of the angioma was not detected."

The large tortuous retinal vein had been observed, but its significance was evidently not appreciated.

Cushing and Bailey,[2] in reporting their case, stated that, so far as they were aware, it was the first in which the histologic diagnosis of the cerebellar lesion had been verified during the life of the patient, which adds interest to the following case, in which the patient is still alive and well.

REPORT OF A CASE

J. R., aged 32, a paper finisher, was first seen by me on Nov. 27, 1926. His chief complaint was failing vision, particularly in the right eye, for nine months. He also complained of severe occipital headaches for the past few months and pain in the back of the neck, occurring more frequently during the past month and worse at night, and so severe some days that he was obliged to remain in bed. A few days prior to examination, he felt dizzy during the afternoon. This dizziness was sometimes accompanied by nausea, but he rarely vomited. In walking he had a tendency to bear to the right, but had never fallen. In 1919, on his discharge from the army, he had first discovered that he could not see as well with the right eye as with the left. At the age of 6 years, he had fallen from a tree, striking his head, and had been in bed for one week. There was no history of other members of the family being similarly affected, but one sister was in the state hospital for

* Submitted for publication, Oct. 12, 1931.

1. Lindau, A.: Studien über Kleinhirncysten Bau: Pathogenese und Beziehungen zur Angiomatosis retinae, Acta path. et microbiol. Scandinav., supp. 1, 1926, p. 1. Zur Frage der Angiomatosis retinae und ihrer Hirnkomplikationen, Acta Ophth. **4**:193, 1927.

2. Cushing, H., and Bailey, P.: Hemangiomas of Cerebellum and Retina (Lindau's Disease), Arch. Ophth. **57**:447 (Sept.) 1928.

the insane. The hospital reported that nothing pathologic was found in her eyes. Two children died shortly after birth, from an unknown cause.

Examination of the eyes showed: In the right eye, vision was 10/200 and with correction 20/100; in the left eye, 20/25-1 and with correction 20/20. The eyes were quiet. The pupils were equal and active to light and in accommodation. There was no nystagmus; associated movements and the peripheral fields were normal.

The results of ophthalmoscopic examination were as follows: In the right eye the media was clear. The disk margin was quite blurred, more above and temporally, and the retina surrounding the disk was edematous. About 2 disk diameters up and temporally from the disk were two small, irregular, whitish patches about the size of the disk, but elongated; these appeared to be retinal exudate. There was a similar smaller patch quite near the disk, above and nasally. The superior temporal artery was greatly enlarged to at least three times its normal size, and along its course there were many aneurysmal swellings varying in size, some twice the diameter of the enlarged artery; on a terminal branch, rather far into the periphery, were several quite large aneurysms as compared with the small branches of the artery. The superior temporal vein was much the same color as the artery but considerably larger; toward the periphery it increased enormously in size, becoming more and more tortuous until in the periphery it disappeared in a vascular tumor mass having the appearance of a tangled coil of enlarged vessels. The other retinal vessels appeared quite normal except that possibly the veins were slightly enlarged. In the left eye, the media was clear and the disk normal, and the veins were a little full. There was a large, irregular, pigmented, whitish, chorioretinal patch extending vertically between the superior and inferior temporal retinal vessels about 2 disk diameters to the temporal side of the macula lutea and about 1 disk diameter in width with a fringe of pigment around the edge.

On Nov. 29, 1926, the patient was admitted to the House of the Good Samaritan, Watertown, N. Y., for observation.

A summary of the general physical findings is as follows: The temperature was 98 F., the pulse rate 80 and the respiratory rate 20. The patient was suffering acutely with severe occipital pain, and movement of the head brought on a paroxysm of pain. The cranial nerves were apparently not impaired. The reflex of the right biceps was more active than that of the left. The left knee jerk was a little more active than the right, but both were exaggerated. The ankle jerks were sluggish, but the right was more active than the left.

After his admission to the hospital, the patient required catheterization, which was never necessary prior to admission. The urine showed a faint trace of albumin, but was otherwise normal. The Wassermann reactions of the blood and spinal fluid were negative. A blood count and chemical analysis of the blood gave normal results. The cerebrospinal fluid was clear and the pressure greatly increased, but the laboratory findings were normal.

An ear, nose and throat examination yielded normal results, except that chronic disease of the left antrum was found.

A provisional diagnosis of cerebellar tumor was made, and the patient was sent to St. Luke's Hospital, New York, where he was admitted on December 9. The report from St. Luke's Hospital adds the following data:

The right pupil was smaller than the left; both were irregular and reacted sluggishly to light and in accommodation. There was nystagmus to the left but no strabismus.

Ophthalmoscopic examination showed a choked disk in the right eye and optic atrophy in the left. (No note was made of the angiomatous condition of the right eye.)

Both aural membranes were dull and slightly injected.

Neurologic examination revealed weakness of the occipitofrontalis muscles. The biceps and triceps were active and equal, and the left knee jerk was exaggerated. There were suggestive Gordon and Babinski signs.

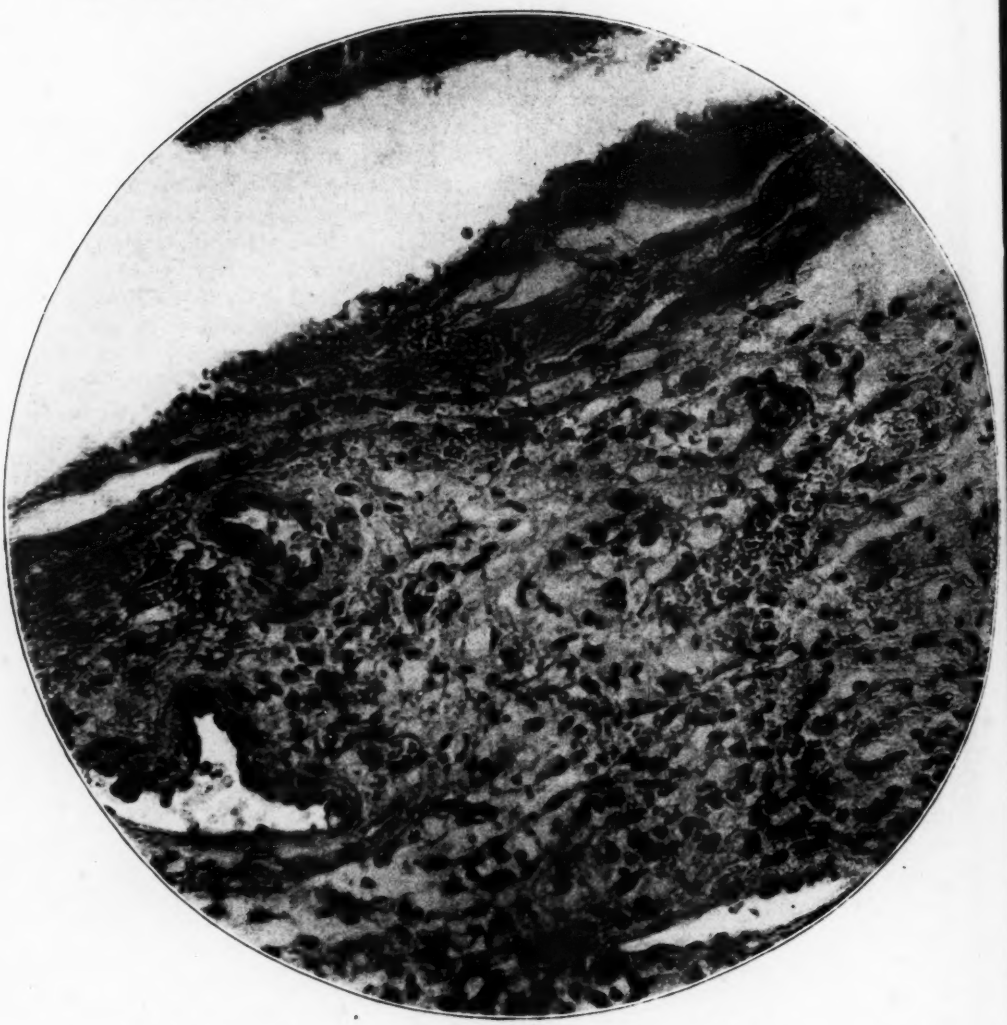

Fig. 1.—Photomicrograph showing many dilated vascular sinuses and small angiomatous areas.

Operation: A decompression was performed, exposing the cerebellum. A cystic tumor was found protruding from below the lower surface of the left cerebellar lobe, and was pushed downward through the foramen magnum toward the midline. It contained quite clear fluid (from 5 to 8 cc.), and the top of the cyst was cut off to be used as a pathologic specimen.

The following pathologic report was obtained: "Macroscopic Examination: The specimen consists of a small piece of fibrous appearing tissue which on section appears hemorrhagic. Microscopic Examination: Sections of the wall of the cyst show a very small amount of cerebellar tissue (figs. 1 and 2), the cells being rather disorganized, small masses of glia infiltrated with blood, and the more solid portion of the tissue being composed of a large number of dilated vascular sinuses embedded

Fig. 2.—Photomicrograph showing changes similar to those in figure 1.

in a glial reticulum in which are a number of rather large clear cells. These cells are probably also glial in origin, having a small compact deeply staining nucleus. Some of the vascular sinuses contain many polynuclear cells, apparently early thrombi forming in the wall. The lining of the cyst is apparently glial only. None of this tissue appears to be neoplastic and many of the changes are inflammatory due to pressure or trauma."

On Jan. 7, 1927, the patient was discharged from St. Luke's Hospital, improved.

Dr. L. C. Knox, pathologist at St. Luke's Hospital, reviewed the slides of the cyst wall removed at the time of operation. She found tiny angiomatous areas, and stated that unquestionably the cyst was one of those arising from and in connection with an angioma, as shown in the accompanying photomicrographs.

On December 10, when I next saw him after the operation, he was having practically no headaches and felt well, but said that he had been unable to see with the right eye since the operation. In the right eye vision was limited to perception of hand movements temporally; in the left eye it was 20/50 and with correction 20/20-3. The loss of vision in the right eye was due to a large detachment of the retina; otherwise the eyes were about the same.

On June 19, 1930, there was no light perception in the right eye; in the left eye, vision was 20/40 and with correction 20/20. The detachment of the retina in the right eye had increased so that only a little of the enlarged vessels could be seen.

On Jan. 30, 1931, the patient wrote that he was working and felt well.

COMMENT

In the sex and age of the patient this case corresponded with the others reported.

The enormous vein with the angiomatous tumor mass in the periphery, the white patches of exudate in the retina and the enlarged artery with aneurysms presents a rather typical picture of angiomatosis retinae, often referred to as von Hippel's disease. This, together with the cerebellar cyst and the angiomatous areas in the cyst wall, seems sufficient to classify the case as Lindau's disease.

That no other members of the patient's family have been found to have the disease does not preclude this diagnosis. Møller,[3] in a recent communication regarding Lindau's disease, stated: "There should be a cerebral tumor plus familial incidence, or retinal angiomatosis plus cerebral tumor, with or without familial tendency to make a diagnosis of Lindau's disease."

This adds a second case of Lindau's disease in which the histologic diagnosis of the cerebellar lesion has been verified during the life of the patient.

3. Møller, H. U.: Familial angiomatosis retinae et cerebelli—Lindau's Disease, Acta Ophth. **7**:244, 1929.

FUNDAMENTALS OF DYNAMIC RETINOSCOPY*

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BOSTON

ORIGINS AND DEVELOPMENTS OF DYNAMIC RETINOSCOPY

The two most important developments of retinoscopy since its introduction by Cuignet in 1873 are cylinder retinoscopy and dynamic retinoscopy. Each of these represents a series of methods that extend the usefulness of retinoscopy far beyond the original conception of the earliest workers. It is especially interesting to note that both these extensions of retinoscopy had their origins as far back as the early nineties of the last century, though their development and practical application came considerably later.

Cylinder retinoscopy, first introduced by Chibret in 1890, was elaborated and developed into a complete system by Jackson in the early nineties. His work, "Skiascopy and Its Practical Application to the Study of Refraction," published in 1895, contains the foundations on which all later work in this method has been built. In the subsequent development, chief credit must be given to Marquez of Madrid and Lindner and Kraemer of Vienna. The latter have reformulated the basic principles and developed a practical technic for everyday work that is most satisfactory. The system is being constantly used by some of the leading ophthalmologists and is also a routine method in some clinics, notably the Fuchs Clinic in Vienna. It is being taken up more and more by American ophthalmologists, and its general spread in the United States is now a matter of time.

Dynamic retinoscopy likewise had its beginnings in the nineties of the past century. In 1895, Prof. R. Greeff (then dozent) applied the dynamic method for the first time when he performed retinoscopy on the eyes of a young boy who was blind in one eye, while the boy was fixing binocularly an object placed very near, e. g., 10, 15 or 25 cm. from the eyes. The amount of accommodation exerted during this act of fixation was determined by locating the point of neutralization. Professor Greeff performed retinoscopy on the two eyes alternately, moving in toward the patient until the initial "against" movement in each eye changed to neutral. His purpose in the test was to determine whether or not the two eyes always exerted equal amounts of accommodation even when one eye was blind. By this objective method he proved that both eyes always accommodated exactly equal amounts.

* Submitted for publication, Oct. 12, 1931.

Shortly afterward, Prof. T. Axenfeld undertook a similar study to determine if the two eyes exerted equal amounts of accommodation in cases of squint with or without associated monocular blindness. He used a similar technic. His method was to have the patient fix binocularly an object, say his own finger, or the examiner's finger held at some close distance, e. g., 10, 15 or 25 cm. and then to perform retinoscopy with a plane mirror, alternating from one eye to the other until he obtained neutralization. As his main object was to prove that the accommodative impulse was always equal in the two eyes even when one eye was excluded from fixation because of a squint, or excluded from seeing because of blindness, he did not make any efforts to determine the absolute amplitude in each case. He succeeded in showing, however, that for each point of fixation the accommodation exerted was always equal in the two eyes. Before determining the accommodative changes by this method of dynamic retinoscopy, Professor Axenfeld applied the usual methods of static retinoscopy, in order to measure the patient's ametropia. The dynamic tests were carried out while the patient was wearing his distance correction.

Several years later, in 1898, Prof. L. Heine, first alone, subsequently in conjunction with Prof. C. Hess, again employed this method of retinoscopy in order to study the mechanism of accommodation and to determine the accommodative amplitude of various animals, birds, dogs, cats, monkeys, etc. They used a concave mirror, worked from a fixed distance of 50 cm. and used lenses for neutralization. The accommodative impulse was produced through electrical stimulation of the exposed ciliary ganglion, and an effort was made to determine the full accommodative amplitude in each case.

All the aforementioned authors, however, made no recommendations for using this method of retinoscopy as an everyday test in order to determine objectively the amplitude of accommodation of the usual run of patient. That the significance of this method as introduced by Greeff, Axenfeld, Heine and Hess was completely overlooked is evidenced from a statement of Landolt,[1] in 1904 that as one cannot hope for an objective method of determining the amplitude of accommodation one must make every effort to perfect the subjective methods for testing the accommodation.

Several years later, in 1902-1903, Andrew J. Cross, an American optician (later optometrist), unaware of the work of the aforementioned ophthalmologists, presented a fairly complete system of dynamic retinoscopy. Mr. Cross, a man of very studious and inquisitive

1. Landolt, in Graefe-Saemisch: Handbuch der gesamten Augenheilkunde, ed. 2, Leipzig, Wilhelm Engelmann.

mind, experimenting with static retinoscopy, came on the idea of making the test not only under conditions when the accommodation was suppressed, but also under conditions when the accommodation, in association with the convergence, was called on for full or partial exertion. Mr. Cross at first thought that by his method of forcing at close fixation plus lenses to the point of reversal latent hyperopia could be uncovered without the use of cycloplegics. He taught this as the most important application of dynamic retinoscopy. Later researches caused a modification of this view in favor of dynamic retinoscopy being primarily a test for near point corrections. However, Cross developed a series of methods which to this day form the foundations on which an extensive superstructure of useful tests have been elaborated by later workers.

It would seem that the need of an objective method for determining anomalies of accommodation has been felt by many refractionists. And so again in 1915 there was another manifestation of a successful effort in that direction. Just as Cross rediscovered and developed dynamic retinoscopy without being aware of the earlier work of Greeff, Axenfeld, Heine and Hess, so now Prof. E. Seidel, unaware of the work of Cross, developed a splendid clinical method of dynamic retinoscopy largely for the purpose of determining accurately the amplitude of accommodation. Unlike Greeff and Axenfeld, who were interested mainly in a scientific investigation without regard to its clinical utilization, Dr. Seidel proceeded primarily from the standpoint of the clinical need of such a method. He did a splendid piece of work, and the reading of it will prove useful and interesting to American ophthalmologists. I hope to present in a future article an outline of his work.

Why has not dynamic retinoscopy made more headway among ophthalmologists? The explanation perhaps is this. The work of Greeff and Axenfeld was conducted more as a laboratory experiment for purely scientific purposes without reference to its practical everyday utilization. The work of Heine and Hess was done with a similar end in view. The extensive work of Cross did not come to the notice of ophthalmologists, as none of it appeared in the medical press. It found some response among nonmedical refractionists, and was especially taken up by those who, like myself, had studied the system directly with Mr. Cross at Columbia University. The splendid contribution of Professor Seidel seems to have been ignored, probably because it was presented during the turmoil of the World War. Seidel apparently did not bother about spreading the method later, as he became interested in other phases of ophthalmology. However, dynamic retinoscopy has now developed into a complete system which offers the ophthalmologist a variety of tests of genuine value. The progressive eye specialists cannot afford to be ignorant of them.

PROCEDURE AND TECHNIC IN DYNAMIC RETINOSCOPY

The series of methods constituting collectively the system of dynamic retinoscopy offers one of the most useful developments made in the practice of retinoscopy in recent years. It offers the ophthalmologist the only objective method for testing the functions of the eye while they are in a state of normal activity. The comfort or discomfort from lenses depends largely on how the lenses affect the associated functions of accommodation and convergence during their constant interplay in the act of single binocular vision. Landolt forcefully expresses this significance, as stated by Walker in *The Journal of the American Medical Association:*

> Landolt again emphasized that the many generations of association of accommodation and convergence have tied these functions so together (pyhlogenetic association) that errors or weaknesses of one must show in the other function. This interassociation is the basis of all our study, and whether appreciated or not, the literature of the phorias and the tropias is made up of efforts to search out the reflex nature of this interdependence.

Dynamic retinoscopy is concerned mainly, though not exclusively, with methods for determining the proper lens correction for comfortable work at close range. To this end it employs principally three tests, one for finding objectively the monocular amplitude of accommodation when each eye is acting alone, one for finding equality or inequality of accommodation while both eyes are simultaneously accommodating and converging and one for determining the lens aid necessary, if any, to correlate best the associated functions of accommodation and convergence in the act of single binocular vision. The technic of each of these tests will be briefly discussed.

To determine the monocular amplitude of accommodation, the doctor, after having determined the distance correction and with this in situ, takes an initial position, say 15 inches from the patient. One eye is occluded, and the patient is asked to fix the other eye on a series of small letters on a small chart which the doctor holds with his left hand 2 or 3 inches (5 or 7.6 cm.) in front of the retinoscope. A transparent chart and a "window" in the luminous retinoscope facilitate illuminating the fixation chart, but any other arrangement will do. The doctor employs the retinoscope preferably just above the edge of the chart, using one or two slow horizontal mirror movements for his observation. He will obtain an against movement if and so long as the eye examined is sharply in focus for the letters on the fixation chart. The doctor then approaches the patient, still maintaining the fixation chart a little in front of his retinoscope until the against movement, which becomes more and more rapid, changes to neutral. The position of the retinoscope at that point locates the near point. A tape measure attached to the trial frame and sliding through the fingers of the hand holding the retinoscope may be used to get the distance quickly and accurately. A similar procedure is then carried out with the other eye. The smallness of the pupil resulting from accommodative effort does not offer any difficulty in observing the light movement when the examiner works so close to the eye. It is advisable

to get the near point located somewhere between 16 and 6 inches (40.6 and 15.2 cm.), occasionally using an auxiliary plus or minus lens, if desired, to bring the near point within that range. The fixation chart is also brought nearer to the retinoscope as the doctor comes closer to the patient, holding it finally only an inch or less from the mirror. The purpose of this advance chart is to arouse a stronger accommodative impulse than is obtained when the chart is placed in the plane of the retinoscope.

To determine equality or inequality of accommodation while both eyes are engaged in seeing, the doctor can use a chart similar to the one used in the monocular test. A small chart about an inch square, stuck on a thin bar to serve as a handle and containing small letters irregularly scattered, serves the purpose very well. The doctor holds this chart a little in front of the retinoscope, taking care that both the chart and the mirror lie along the median line of the patient. By this arrangement the mirror and chart are always equally distant from each of the patient's eyes. The test may be made from any convenient near distance, such as 16 inches, and the examiner slowly approaches the patient. It is often not necessary in this test to come as close to the patient as in the monocular test. For here one is aiming only to determine equality or inequality in the accommodative amplitude of the two eyes, and this will frequently show itself even before the absolute near point of each eye is reached, by a difference in the extent and rapidity of the against movement in the two eyes. The doctor rapidly and alternately uses the retinoscope on each eye, one or two flashes along the horizontal meridian, being generally sufficient for observation. Inequality of accommodation in the two eyes may be only apparent and due to incorrect distance correction, or it may be real. The latter may be caused by early senile changes in one crystalline lens, early glaucomatous changes, in one eye, or a beginning paralysis of the ciliary muscle in one eye. These need be further investigated. It is only by making a binocular test as previously described that a slight inequality of accommodation can be definitely detected. A comparison of the near point of the two eyes as monocularly determined is of value only in cases in which the inequality in accommodative amplitude is really marked. Otherwise, such comparison is of no value as it is extremely difficult to determine accurately at close range small differences of distance.

To determine the lens aid necessary, if any, in order to produce a comfortable balance between the accommodation and convergence, the doctor chooses an examination distance corresponding to the habitual working or reading distance of the patient. The doctor attaches a small chart to the retinoscope, preferably directly above the peep-hole containing letters or figures irregularly arranged and of a size to be easily read under a blur of 0.50 to 1.00 diopter, say from, 3 to 4 mm. large. The patient, in order to keep his attention on the chart, is requested to pick out certain letters or figures and name the letters or figures that are repeated once, twice or three times, and so on. The doctor, with his instrument in the median line of the patient, then does retinoscopy on each eye in turn, again using just one or two movements along the horizontal meridian for his determinations. The patient, during the test, wears his statically found correction so as to eliminate the influence of ametropia on the near point correction.

The initial observation will almost always be a "with" movement. The examiner then places plus lenses, in intervals of 0.25 or 0.50 diopter, before both eyes until he gets a distinct against movement. He does not stop at neutralization, but continues beyond until he gets an against movement. The prereversal lens, that is the one just weaker than the one that caused the against movement is taken

as the basis for the required lens addition. Thus if it took plus 2.00 to cause reversal, plus 1.75 is the strongest lens giving neutral, and is conveniently termed the high-neutral. This lens, however, must be reduced somewhat, usually from 0.50 to 0.75 diopters. This reduced lens represents the lens aid necessary over and above the distance correction in order to harmonize comfortably the accommodation and convergence at the distance examined. This lens aid, by the way, is required whatever the age of the patient, and it is amazing how many young adults find relief from troublesome eye strain in the wearing of bifocals thus determined.

The rationale of the foregoing procedure is simply this. When the eyes fixate the chart, they may or they may not use enough accommodation to focus the letters perfectly. There is no urge for exact focusing since the letters, and figures can be readily recognized even under a blur of 1.00 diopter. By interposing plus lenses even after neutralization was obtained, there was no urge for the accommodation to relax, for the very same reason, and any relaxation that did take place must have been due in the interests of arriving at a physiologically comfortable balance with the associated convergence. A reduction of from 0.50 to 0.75 diopters from the high-neutral lens has been found necessary in practice, though the explanation for it has long baffled scientific workers. The most acceptable explanation, as given by Professor Southall, is that the overcorrection is due to the monochromatic aberration of the eye which is especially manifest at close range. Be that as it may, the basic correction as found by the test, the high-neutral lens, serves as a definite starting point from which a slight variation may be made in the light of other tests.

THE PATHOLOGY OF MELANOSIS AND OF BENIGN MELANOMAS OF THE CILIARY BODY*

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Benign melanomas of the ciliary body are rarely found, and then usually accidentally during the routine examination of serial sections. The pathologic diagnosis can at times be difficult. One should differentiate the circumscribed, sharply defined, pigmented, tumor-like area that can be called a pigmented nevus or benign melanoma from the diffuse pigmentation present in association with general ocular melanoses and from those local diffuse pigmentations, sometimes in the form of streaks, that one often finds normally in the ciliary body of eyes otherwise not excessively pigmented.

Normally, the ciliary body contains some pigmented cells in its stroma. The degree of pigmentation depends not only on the number of pigmented cells present, but on the amount of pigment granules present in these cells and the color of the granules themselves. These vary with age, sex and type. Brunettes, as a rule, possess pigmented cells containing relatively more and darker pigment granules than blondes. In albinos, these cells are present, but contain no pigment. In the colored races and in ocular melanoses the stroma of the entire uveal tract contains many of these deeply pigmented cells. These are large spindle-shaped and star-shaped cells with many irregular processes. The pigment is in the form of regular spherical or ovoid granules, which are most closely aggregated in the processes and about the periphery of the cells. The nucleus is small, may be short, rodlike, polygonal or roundish and is surrounded by a relatively large amount of cytoplasm. When the cells are filled with pigment, they become plump, the processes shorter and the nuclei frequently flattened and displaced toward the cell periphery. The cells themselves often become polygonal or roundish with no processes.

As a rule, the degree of pigmentation of the iris gives a more or less accurate idea of the amount of pigmentation present in the rest of the uveal tract. However, such is not always the case. E. Fuchs[1] found three cases of a quite unpigmented iris in association with a

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* From the First Eye Clinic, University of Vienna, Prof. Josef Meller, Director.

1. Fuchs, E.: Ueber Pigmentierung, Melanom und Sarkom der Aderhaut, Arch. f. Ophth. **94**:43, 1917.

darkly pigmented choroid. Two of these eyes were removed for melanosarcoma.[2] He also reported another interesting case in which the iris was brown while the choroidal stroma was quite pigment free. The following two cases illustrate the picture that one finds in a normal native eye, or in a general diffuse melanosis, for comparison with a case of a local diffuse melanosis in the ciliary body of an eye otherwise not excessively pigmented:

In the normal native eye shown in figure 1, one sees a large number of deeply pigmented melanoblasts in the stroma of the ciliary body, between the muscle fibers, and extending with the stroma into the sclera about one of the anterior ciliary arteries.

The second case (fig. 2) was that of a white woman, aged 28, who died of renal disease, i. e., secondary contracted kidney. The fundi showed a neuroretinitis albuminurica. The eyes were sent to the laboratory of the First Eye Clinic for histologic examination. On a study of serial sections, a large number of branching spindle-like cells filled with pigment and identical with the branched pigment cells in the choroidal stroma, as well as roundish ovoid cells rich in cytoplasm but with small compact nuclei, were found to surround the muscle fibers in the lower seven eighths of the outer quarter of the ciliary body on the nasal side of each eye. Very little pigment was found to be lying free in the stroma. The rest of the uveal tract was not excessively pigmented. The muscle fibers themselves were not involved. This case can be added to the four cases of local diffuse melanosis of a portion of the uveal tract described by Fuchs. In his cases the choroid and the iris were respectively involved. Here the site was in the ciliary body.

It was generally agreed with Ribbert and Fuchs, for many years, that the "chromatophores," i.e., the pigmented cells in the uveal stroma, were specific mesoblastic cells having a differentiated function of producing pigment and forming a part of the constituent connective tissue stroma cells of the uveal tract. Ribbert[3] carried his conception of the "chromatophore" origin of all the tumor cells of melanomas from the skin to the eye, finding his strongest support in the structure of uveal melanomas. He regarded the different forms of tumor cells found there as developmental stages of the same cell, the typical, primitive, ameboid, mesoblastic chromatophore. The round unpigmented tumor cell was thought by him to be a chromatophore proliferating at a stage of its

2. Fuchs, E.: Normal pigmentierte und albinotische Iris, Arch. f. Ophth. **84**:521, 1913.

3. Ribbert: Das Chromatophorom: Melanom, im Geschwulstlehre für Aertze und Studierende, Bonn, F. Cohen, 1914, p. 318; Ueber das Melanosarkom, Beitr. z. path. Anat. u. z. allg. Path. **21**:471, 1897.

development as yet immature for the production of pigment, while the pigmented spindle-shaped cells in melanotic sarcomas were regarded as mature.

To these tumors, whether benign or malignant, pigmented or nonpigmented, Ribbert gave the name of "Chromatophorom" in view of his conception of their mesoblastic chromatophore origin.

Fuchs [1] did not entirely agree with this, as he and others had seen sarcomas with pigmented, round and unpigmented spindle-shaped cells. He [4] rather held the nonpigmented forms to have arisen from the adventitial cells of the vessels.

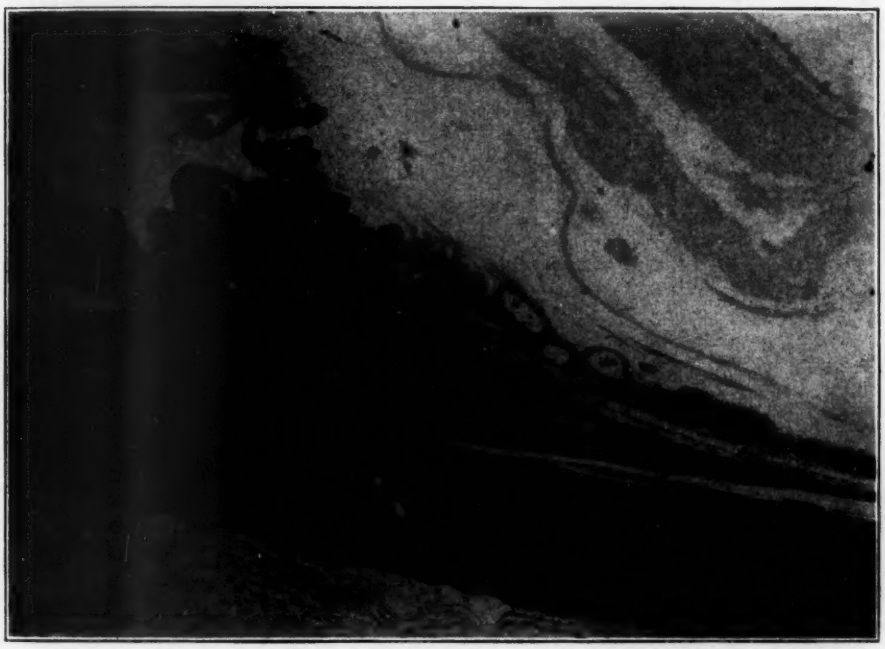

Fig. 1.—Photomicrograph of horizontal section (stained with hemalum and eosin) of a normal native eye showing large numbers of deeply pigmented melanoblasts in the stroma of the ciliary body between the muscle fibers and extending with the stroma into the sclera around one of the anterior ciliary arteries.

Of recent years, much work has been done and increasing support has been given to the view that most, if not all, of the branching pigmented cells found in a uveal stroma are derived from the ameboid pigmented cells of the retinal epithelium that have wandered in during fetal life. They are the true "melanoblasts" or pigment producers and not merely melanophores or "chromatophores," or pigment carriers, as their name would imply.

4. Fuchs, E.: Das Sarkom des Uvealtractus, Vienna, Wilhelm Braumüller, 1882, p. 126.

Kölliker's [5] embryologic investigations on human embryos showed that pigment granules appeared in the retinal epithelial cells in the fourth month, that is, before blood vessels entered the retina. Spencer [6] found that not until the seventh month did pigmented cells appear in the choroid. He thought that the pigmented cells were primarily developed around the neural tube essentially for the protection of the central nervous system. Dawson [7] found that the choroid remained unpigmented until long after pigment appeared in the epithelium of the embryonic retina.

Wieting and Hundi,[8] from their analogy of the embryogenesis of the pigmented cells of the choroid to those of the corium, concluded that

Fig. 2.—Photomicrograph of horizontal section (stained with hemalum and eosin) of the eye of a white woman, aged 28, who died of renal disease. A local diffuse melanosis is present involving the lower seven eighths of the outer quadrant of the ciliary body.

melanomas of the interior of the eye arose from the epithelial cells of the retina, whether dispersed in the choroid or occurring as misplaced elements.

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5. Kölliker: Ueber die Entstehung des Pigmentes, Ztschr. f. Wissensch. Zool. **44**:713, 1887.

6. Spencer: Melanosis, Brit. M. J. **2**:907, 1923.

7. Dawson, James W.: The Melanomata: Their Morphology; Histogenesis, Edinburgh M. J. **32**:501 (Oct.) 1925.

8. Wieting and Hundi: Melanin Pigmentierung, Beitr. z. path. Anat. u. z. allg. Path. **42**:23, 1907.

Lagrange,[9] Leber [10] and Mitvalsky [11] regarded the pigmented cells in ocular sarcomas as derivatives of the pigmented retinal epithelium that have wandered in.

Kromayer [12] and Judalewitsch,[13] supporting the epithelial origin of nevus cells, saw not only a transformation of the epithelial cell into a cell morphologically like connective tissue, but also a transformation of the functioning character of the cell or a "desmoplasia;" the cell, formerly epithelial, could now function as a connective tissue cell and produced fibrils. While Dawson [7] did not agree with the theory of desmoplasia, he showed in his excellent monograph on the melanomas by an admirable series of illustrations and photomicrographs, what an extreme morphologic differentiation the epithelial cell can undergo, especially in the various developmental phases of transformation of the neuroepithelial pigmented cells of the retina to the so-called pigmented spindle cell sarcoma, and in the congenital moles of young children, in which he traced the different stages in the development and segregation of the epidermal cells into the tumor.

Meirowsky's [14] experiments on overexposure of the skin to Finsen lamp rays showed, in the brown pigmentation thus produced, that the cells of the basal layer through their intense activity were laden with pigment granules, while the corium was free from pigment, except by diffusion.

Bloch,[15] experimenting with the "dopa (dihydroexphenylalanin) oxydase" reaction on frozen sections of skin, found that the pigmentation was limited to the epidermis and provided further proof of the epithelial origin of the melanoblast.

That the branching pigmented cells found in the uveal stroma are of epithelial origin is most convincing, I have already shown, on

9. Lagrange: Traité des tumeurs de l'oeil, de l'orbite et des annexes, Paris, G. Steinheil, 1901, vol. 1, p. 336.

10. Leber: Ueber die Aderhautsarkome und die Herkunft ihres Pigmentes, Arch. f. Ophth. **44**:683, 1897.

11. Mitvalsky: Zur Kenntnis der Aderhautgeschwülste, Arch. f. Augenh. **28**: 321, 1894.

12. Kromayer: Die Desmoplasie der Epithelzellen, Monatsh. f. prakt. Dermat. **41**:477, 1905.

13. Judalewitsch: Zur Histogenese der weichen Naevi, Arch. f. Dermat. u. Syph. **58**:15, 1901.

14. Meirowsky: Zur Pigmentfrage, Monatsh. f. prakt. Dermat. **42**:541, 1906; **43**:155, 1906; **44**:111 and 166, 1907; Ueber Pigmentbildung, Frankfurt. Ztschr. f. Path. **2**:438, 1908-1909.

15. Bloch, A.: Die Dopa-Oxydase, Ztschr. f. physiol. Chem. **98**:226, 1916; Zur Pathogenese der Vitiligo, Arch. f. Dermat. u. Syph. **124**:209, 1917-1918; Das Problem der Pigmentbildung in der Haut, ibid. **124**:129, 1917-1918; Ueber die Entwicklung des Haut- und Haarpigmentes, ibid. **135**:77, 1921.

referring to the researches in embryonal pigmentation, the genetic processes in melanomas that show a transition to malignancy and the analogy in the genesis of skin and uveal melanomas and in the artificial production of pigmentation.

One of the striking features of these cells is, of course, the pigment that they contain. As far as is known, the cell produces the pigment synthetically by the action of an intracellular ferment called oxydase, formed by the cell as its specific differentiated activity, on a certain colorless derivative of albuminoid character called melanogen, the mother substance of melanin which turns it brown or black. Melanin occurs in brownish or black granules, usually intracellular, and necessarily varies in amount with the metabolic activity of the cell.

The granules contain carbon, hydrogen, oxygen and about 9 per cent sulphur, but no iron, phosphorus, chlorine or fat. They are quite insoluble in acid and alkalis, are bleached by hydrogen dioxide and are blackened with silver nitrate. Much work has been done on the origin of this pigment, its composition and its behavior, especially by Bloch.[15] By using a 1 per cent solution of dihydroxyphenylalanin isolated from the embryo of the broad bean, he found that frozen sections of skin stained a smoky gray, deepening to brown and black, by the formation of granules identical with melanin. This he called the dopa reaction. All the basal cells of epidermal origin he found to give a positive dopa reaction. He found the mesodermal cells to be negative, as were the chromatophores or passive carriers of pigment. Nonpigmented nevus cells gave a faint positive reaction, and the cells of the melanomas a well marked reaction. Bloch also showed that epinephrine is the only other substance besides dihydroxyphenylalanin or dopa that is oxidized by the intracellular oxydase, and that both epinephrine and dopa are pyrocatechin derivatives. Melanogen is, in all probability, a pyrocatechin derivative closely allied to 3-4 dihydroxyphenylalanin. Melanin is thus the end-product of a pyrocatechin exchange. Anomalies of pigmentation may therefore be due to an altered metabolism causing a variable destruction of the complex protein molecule.

Two types of cells that contain melanin pigment are present in melanotic tumors: true tumor cells that produce the pigment and reproduce potential pigment-producing cells, and, secondly, a few phagocytic cells of connective tissue or endothelial origin that ingest the pigment left behind by melanoblasts as they undergo cytolysis. The latter melanophores may be branched, but are usually rounded cells filled with large granules of melanin.

The term melanoblast is appropriate for the branching pigmented cell of the uveal stroma because it emphasizes the distinctive specialized function of that cell. The term melanoma is useful as it emphasizes the

specific character of the cells of the tumors that they give rise to. The use of the term chromatophore should be limited to the phagocytic mesoblastic pigment carrier cells. Ribbert and his followers, through adhering to the term chromatophore rather than melanoblast, have given rise to some confusion; similarly, "chromatophorom" is a misnomer if the neuro-epithelial origin of the melanoma be accepted.

Eight cases of benign melanomas or nevi of the ciliary body were found in the literature.

E. Fuchs [1] described three cases. In all instances the finding of the growth was accidental. Two of these eyes were removed following excessive traumatism.

In the first case, the melanoma was present on the temporal side in front of the pars plana of the ciliary body, which was here slightly thickened. The pigmented cells were so numerous that they filled the stroma and extended to nearly the entire width of the ciliary body in this area, from the lamina vitrea to the outer muscle fibers. The cells in the center of this mass were roundish or polygonal, but longer and more spindle-like toward the periphery.

In the second case the melanoma was in the upper part of the lower half of the ciliary body. The pigmented area was 1.2 mm. long and extended from the vitreous to the outer muscle fibers. "At the periphery of the tumor, where less pigment was present, one could see typical individual chromatophores." Some of these cells were roundish, with plump processes.

The third eye was enucleated because of a choroidal leukosarcoma made up of round and spindle cells, extending from the posterior pole of the eye to the lens. A melanoma was present in the upper portion of the lower half of the ciliary body. It did not occupy the entire thickness, but left the outer bundles of the meridional fibers free. The cells were described as typical "slim chromatophores."

Foster Moore [16] described a case of melanoma in the choroid with a more diffuse group of similar large spindle-like pigmented cells in the ciliary body. J. Schappert-Kimmyser [17] considered the lesion to be a melanoma as she also did in the case reported by Heine [18] as melanosis of the ciliary body in association with a leukosarcoma of the choroid. The whole eye was densely pigmented and obviously melanotic.

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16. Foster Moore, R.: Four Cases of Melanoma of the Choroid with a Pathological Examination in One Case; and One Case of Unusual Chronicity After Dissemination of a Melanotic Sarcoma Had Occurred, Roy. Lond. Ophth. Hosp. Rep. **19**:411, 1914.

17. Schappert-Kimmyser, J.: Die Frequenz der sogenannten Uvealmelanome in Augen mit und ohne Sarkom, Arch. f. Augenh. **100-101**:46, 1929.

18. Heine, L.: Ueber Melanose und Sarkose des Augeninnern, Arch. f. Ophth. **3**:33, 1923.

Sattler,[19] found in the ciliary body of a man, 74 years old, a melanoma 2 mm. long by 0.75 mm. wide.

J. Schappert-Kimmyser [17] described two cases as melanoma of the ciliary body. One occurred in a sarcomatous eye in which the sarcoma of the choroid was largely pigment free. The melanoma in the ciliary body was 1.13 mm. long by 0.2 mm. wide and separated from the pigment epithelium by a thin layer of vessels. At the periphery were round cells looking like strongly pigmented clump cells of the iris. The other cells were longish and relatively large with rather long, darkly stained compact nuclei. Some had larger, rounder nuclei. One cell at the margin was multinuclear. In this same case, Schappert-Kimmyser described a melanoma of the choroid composed of spindle cells with thin rodlike dark nuclei, somewhat resembling the cells in the melanoma of the ciliary body.

The second case was in a nonsarcomatous eye. A pigmented mass, 1.1 mm. long by 0.12 mm. wide, was found lying between the bundles of muscle fibers and was composed of a deeply pigmented spindle-like cell. Toward the inner half of this area, the cells were more roundish. She stated that in the depigmented sections it was difficult to distinguish between the muscle cells, the connective tissue and the cells of the tumor.

The histopathologic investigation of an eye removed from a private patient of Prof. J. Meller was found to be so pertinent to the subject under study that the case merits being reported here in full.

REPORT OF A CASE

Mrs. B. H., 42 years of age, stated that she suffered from inflammation of both eyes following an attack of measles when she was 3½ years old. The cornea became ulcerated and perforated. A little later, some operation, probably an iridectomy, was performed on each eye.

The left eye soon began to shrink. Over this atrophic eye the patient wore a prosthesis. She did not see a physician for a good many years, though her eyes troubled her from time to time. Finally, in May, 1929, she came to Vienna for medical aid because of late her eyes had become redder, more tender and painful. Her vision had been very poor as long as she could remember.

The right eye showed a moderate degree of ciliary injection, numerous old eczematous scars with vascularization, some precipitates on the back of the cornea and a coloboma of the iris, downward and inward. The tension was raised about plus two. Vision was 6/60. The left eyeball was found to be blind, shrunken and tender to pressure. Some ciliary injection was present. The cornea showed distinct aplanation and degenerative changes. The question of a probable sympathetic disease was raised at this time.

On June 26, 1929, the left eye was enucleated under local anesthesia and the eyeball fixed in Müller's fluid. So much bone was found to be present that the

19. Sattler: Die bösartigen Geschwülste des Auges, Leipzig, S. Hirzel, 1926, p. 96.

eye had to be decalcified with 5 per cent nitric acid. After embedding in celloidin, serial sections were prepared and stained with hemalum-eosin.

The histologic observations were: The cornea showed a marked aplanation. Many scars were present, with numerous superficial and deep vessels. At about the center of the cornea, Bowman's and Descemet's membranes were absent. The corneal lamellae were here entirely replaced by a well formed mature scar tissue, enclosing here and there some pigmented cell remains. In some sections, this area was seen to be angulated, thin and lined with pigment. In one angle of the central scar, one could see a few incarcerated smooth muscle fibers. This obviously must have been the site of the perforation with subsequent leukoma adherens. The endothelial lining of Schlemm's canal was replaced by connective tissue and the lumen destroyed. The anterior chamber, including the infiltration angle, was practically obliterated by the almost complete anterior synechia of the iris to the back of the cornea. There were, however, small narrow gaps where the surface of the iris was covered by a membrane that was probably secreted by detached cells from Descemet's endothelium of the cornea, giving the appearance of a second Descemet's membrane. Much proliferation of the pigment epithelium was present, especially in the pupillary area, where the large tufts of pigment epithelium much resembled those normally present in the horse. The stroma of the iris itself was atrophic. Numerous clump cells, as well as few melanoblasts, were present. Only a few of the larger vessels remained with greatly thickened, hyaline, degenerated walls. On the temporal side, an incomplete iridectomy had been performed. The pupillary area was occluded in part by proliferated pigment epithelium, partly by a thick mass of connective tissue, extending nasally between Descemet's membrane and the iris, and by the ossified remains of the lens. In some sections, one saw bits of lens capsule, surrounded by bone, and some remains of a proliferated capsular epithelium. The retina was completely detached and much atrophied, though in parts the structure could still be made out. Much glial and some epithelial proliferation and cystic degeneration were present. The vitreous, now detached and consisting chiefly of connective tissue and capillaries, lay in the anterior part of the vitreous chamber between the ciliary body, ossified lenticular remains and detached retina. Some fresh hemorrhages were present. Numerous foci of pigmented and nonpigmented detached proliferated ciliary epithelium—the so-called Dalen's foci—were seen. The choroid was chiefly replaced by connective tissue and by a very extensive bone formation. This bone surrounded the optic disk and extended upward in a broad band as far as the pars plana of the ciliary body. Numerous fat cells were present in the stroma, between which one found spindle-shaped and star-shaped pigmented cells.

The lamina vitrea showed extensive cuticular degeneration in the form of numerous Drusen bodies, especially about the ora serrata and partly over the ciliary body.

The optic nerve was atrophic. There was much proliferation of neuroglia and connective tissue.

The ciliary body was atrophic and thin. Some remains of ciliary muscle were to be seen above. The parenchyma was relatively poor in cells and blood vessels, and contained but few pigment cells. The ciliary processes showed extensive hyaline degeneration.

Tumor.—In the parenchyma of the pars plana of the ciliary body, on the nasal side of series 22 to 30, lay a blackish-brown pigmented mass (fig. 3). This, in part, occupied the entire width of the ciliary body, which in this area was comparatively wide and bulged slightly into the vitreous. Above this mass, remains of

ciliary muscle were to be seen, with occasional fibers extending downward, chiefly externally, as far as the ora serrata. Between these and below the mass were some well preserved nerve fibers.

Internally, the tumor was bordered by a broad band of connective tissue. External to the tumor, thin streaks of connective tissue could be made out extending downward into the choroid.

The tumor itself, measuring 1.3 mm. in length and 0.9 mm. in width, was sharply defined and seen to be made up, in the main, of closely packed brownish-black pigmented cells. In the inferior half the pole was somewhat rounded. Here one saw roundish and polygonal cells extending for a short distance into the stroma. Superiorly, the mass presented a more columnar fimbriated appearance because of interrupting bands of connective tissue. Here, too, one saw a few pigmented cells extending as far as the ciliary muscle remains.

The epithelium was detached from this part of the ciliary body. Opposite the middle of the mass the elastic lamina was broken; the upper end was split into a brush of numerous fine fibrils. Some of these pigmented cells extended into the internal band of connective tissue as far as the lamina vitrea and, externally, between connective tissue nerve and muscle fibers, in some sections as far as the sclera. In other sections the mass occupied the entire width of the ciliary body. The sclera itself contained little pigmentation.

A few strands of smooth muscle were seen in some sections to lie at the external margin of the mass. They were surrounded by pigmented cells, but they themselves contained no pigment.

To make histologic study possible, depigmentation by means of a weak solution of potassium permanganate and oxalic acid was resorted to. Sections were then stained with hematoxylin-eosin, with Weigert's iron hematoxylin and eosin and by the van Gieson method.

Large plump spindle-like cells with a finely granular cytoplasm, containing compact roundish, ovoid and rodlike nuclei, made up the main mass of this tumor. In the upper half, these cells were arranged in interlacing bundles. In the lower half, the arrangement of these cells was more irregular and whorl-like. There was, however, no sharp division into this arrangement, so that in areas one could see horizontal and longitudinal bundles, cross-sections of bundles and the irregular whorl-like arrangement of cells (fig. 4).

In addition to this, there were many roundish polygonal cells showing one or more processes, rich in cytoplasm and containing relatively small, roundish and, at times, triangular and polygonal nuclei. These were more prevalent in the lower half and about the periphery of the tumor. The nuclei were mostly at the cell margins and were flattened as if pushed aside by a cytoplasm swollen with pigment. They were compact and so densely pigmented that no nuclear structure or nucleoli could be distinguished. No mitotic figures or polychromatism were seen.

With the van Gieson method, one saw distinctly, surrounding these various arrangements and between some of the cells themselves, the sharply defined and, in part, broad bands of connective tissue. In places these bands showed hyaline degeneration. In certain areas, some paler looking necrotic cells were seen bordering on this fibrous tissue. The depigmented cells of the mass stained a pinkish yellow, the muscle fibers a dark brown and the ciliary epithelium and the nerves a lighter brown.

With the Weigert iron hematoxylin stain, the muscle fibers of the ciliary body and in the vessels were bluish back and the connective tissue pink, whereas the depigmented cells of the tumor stained grayish purple.

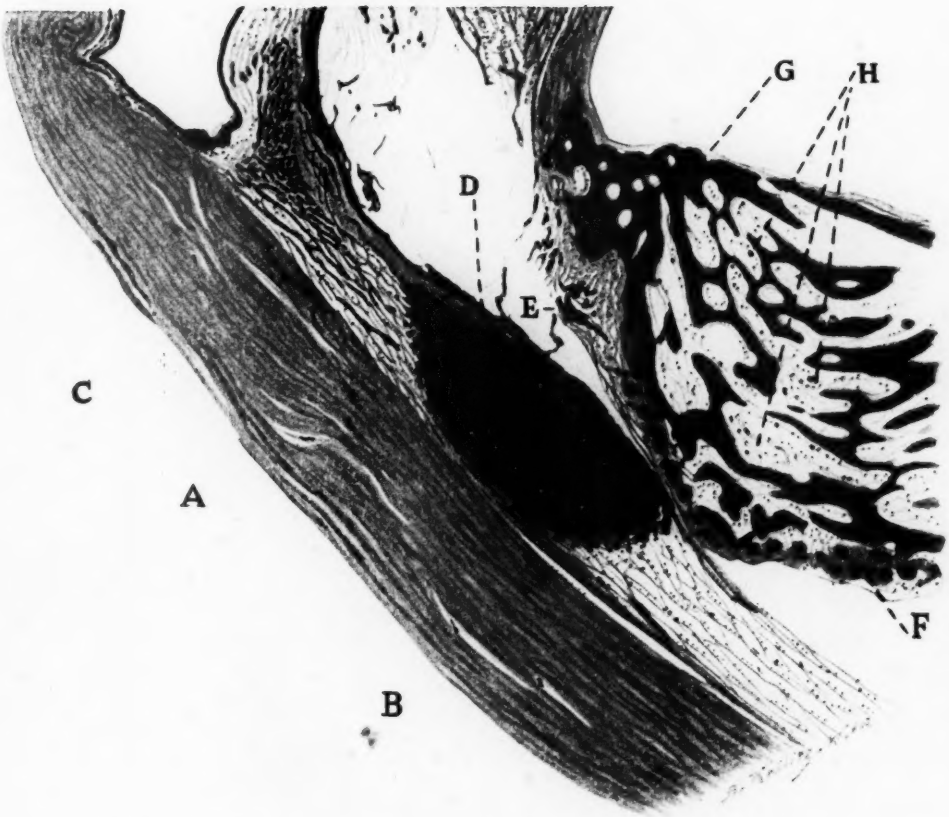

Fig. 3.—Decalcified section stained with hemalum and eosin. *A*, a blackish-brown pigmented tumor with (*B*) a rounded lower pole and (*C*) columnar fimbriated appearance of the upper half due to interrupting bands of pink-staining connective tissue. Note (*D*) the broad band of connective tissue internal to the tumor mass, (*E*) Dalen's foci, (*F*) Drusen bodies, (*G*) bone formation and (*H*) fat cells with pigmented cells (melanoblasts) in the stroma.

The pigment was chiefly intracellular in the form of numerous roundish large granules and, to a lesser extent, of fine dustlike grains of blackish-brown coloration. They seemed to fill the cell, to swell it out and to actually displace the nucleus toward the cell periphery. Some pigment lay in clumps in the connective tissue stroma. No muscle cells were found to contain pigment. The reaction for iron was negative.

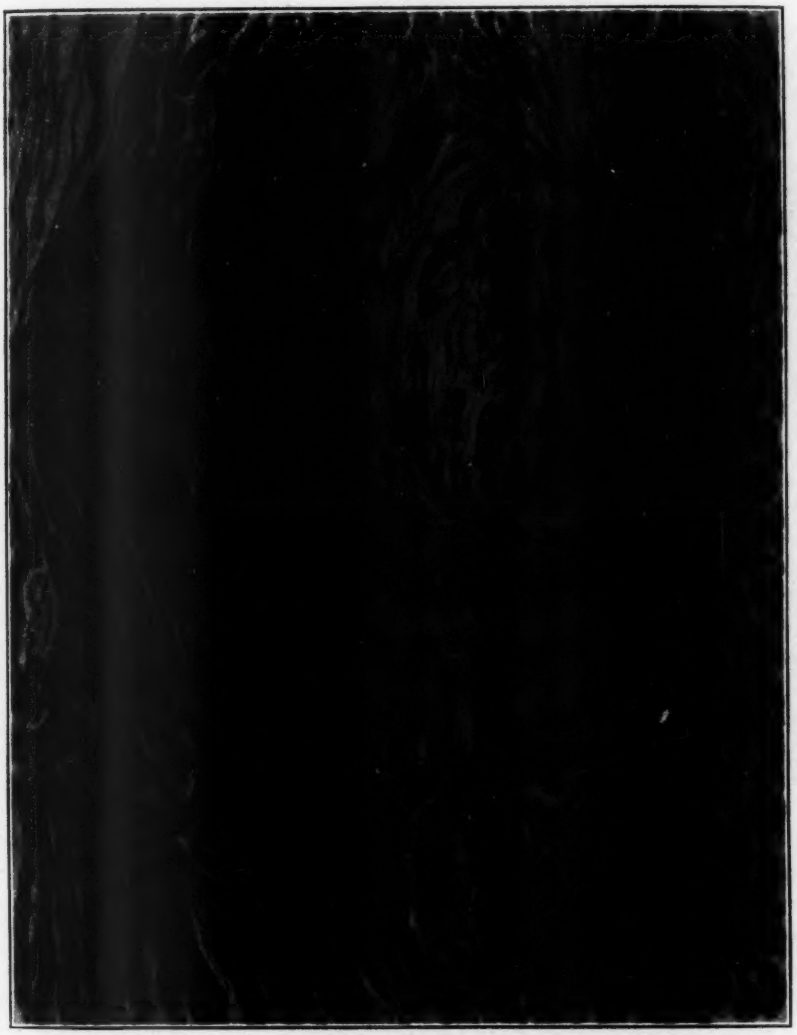

Fig. 4.—Decalcified, depigmented, celloidin section stained with Weigert's iron hematoxylin and eosin. Note the horizontal and longitudinal bundles, cross-sections of bundles and irregular whorl-like arrangement of cells with varying connective tissue content between the bundles and cells, some of which are paler and necrotic looking. Numerous roundish, polygonal cells rich in cytoplasm are present with small compact nuclei frequently displaced toward the cell periphery. One sees numerous capillaries.

Sections stained with orcein showed a rather interesting reaction of the elastic tissue to the tumor growth (fig. 5).

While there was obviously some compression of the elastic fibrils at the periphery, the larger elastic fibrils, which could be seen to continue with but little destruction through the whole length of the tumor area, appeared distinctly to be forced apart by the densely packed pigment-filled cells.

COMMENT

Of the eight cases of benign melanomas or nevi of the ciliary body found in the literature, only the three reported by E. Fuchs presented

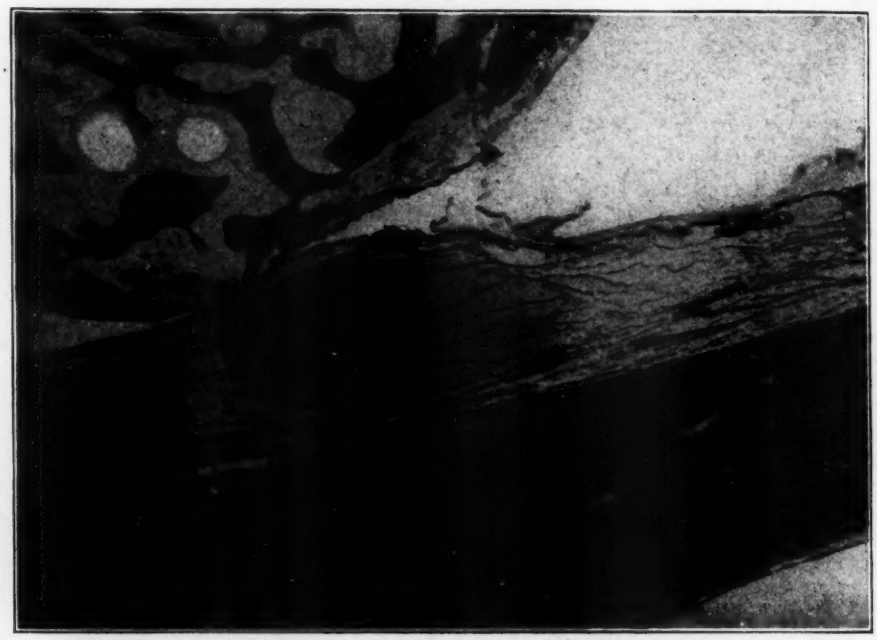

Fig. 5.—Photomicrograph of depigmented section stained with orcein. Note the compression of elastic fibrils at the periphery, larger elastic fibers continuing through the whole length of the tumor area and distinctly forced apart by the densely packed cells, and the rupture of the elastic lamina with splitting of the upper end into a brush of numerous fine fibrils.

a circumscribed, sharply defined tumor-like area. Heine himself described his case as a melanosis of the ciliary body in association with a leukosarcoma of the choroid. The whole eye was densely pigmented, and obviously a general diffuse melanosis was present. It seems rather interesting that the malignant growth was relatively unpigmented.

Foster Moore, in describing his case, stated that "the mass formed a group of pigmented cells amongst the fibers of the ciliary muscle rather than a circumscribed tumour." In the cases cited by Sattler and by J. Schappert-Kimmyser the growth occurred in the form of long

thin streaks of pigmented cells in the stroma of the ciliary body between the muscle fibers. From their description, these cells were chiefly melanoblasts, more or less identical with the other melanoblasts of the uveal stroma. They did not present a sharply defined, tumor-like appearance, but rather a normal variation of the pigmentation that one usually finds present in the ciliary body.

The case of Mrs. B. H. opens other avenues of interest. From the history and histologic examination one can say that the patient had suffered from an eczematous keratitis, that the cornea perforated, that an intense uveitis followed, that an iridectomy was later attempted and that atrophy of the bulb with extensive bone formation subsequently took place. Further examination revealed, quite accidentally, the deeply pig-

Fig. 6.—Photomicrograph of the periphery of the tumor area showing a large branching epithelial-like cell at the center of the field.

mented, sharply defined, tumor-like mass already described, occupying in part the entire width of the ciliary body and causing it to bulge into the vitreous. The pigment so obscured the structure that a diagnosis without depigmentation would be impossible. No local hemorrhages were found in this area. The pigment was chiefly intracellular. All the cells were densely packed with regular dark brown granules, readily bleached by potassium permanganate and oxalic acid. The iron reaction was negative. One has to conclude that the pigment was melanin and most likely produced by the cells themselves.

The spindle-shaped, roundish and polygonal cells rich in cytoplasm, swollen with pigment, the short thick processes and the small compact darkly stained nuclei showing no definite structure or nucleoli were very different from sarcoma cells with the large nuclei and nucleoli, the mitotic

figures, the polychromatism and the relatively little cytoplasm present. Rather, they resembled and were chiefly benign melanoblasts activated to a slow proliferation and metabolic activity of pigment formation.

The roundish and polygonal cells bore much more resemblance to epithelium than to connective tissue (figs. 4 and 6). A few cells were undoubtedly phagocytes. The granules of the phagocytic cells were more globular and less amorphous, and the cells themselves more rounded, than the true branching melanoblasts. The spindle-shaped and star-shaped pigmented cells in association with the fat cell formation and ossification can also be regarded as melanoblasts of neuro-epithelial origin, namely, from detached pigment cells of the retinal epithelium.

By force of much strong evidence, one can reasonably agree with Dawson,[7] who said:

> Melanin pigmented tumours are regarded as having their origin in epidermal or neuroepithelial cells, and melanin pigment formation in the body is regarded therefore as exclusively an ectodermal function. It is more natural and simple to assume that such a highly differentiated function is concentrated in specifically differentiated cells and the epithelial cells of the body are admittedly more capable of carrying out this function.

No ganglion cells and no nerve fibers were found in the tumor, thus excluding any relationship with a neurofibromatosis.

Much has already been learned from the analogy of nevi of the skin to nevi of the uveal tract. In this particular case two further features were very evident that have been but scantily referred to in the literature. The first is the large amount of fibrillar and hyaline connective tissue present (fig. 1). The broad band internal to the tumor, the numerous fine fibers between cells and the broader bands between bundles gave the upper half of the tumor its fimbriated appearance. About this fibrous tissue some paler staining necrotic looking cells were seen (fig. 4).

In the skin it is quite common to find that as the nevus cells atrophy there is an increase in fibrillar intercellular stroma in all gradations to complete replacement of cell groups by fibrous tissue. This often shows hyaline degeneration.

E. Fuchs, in his "Das Sarcom des Uveal tractus," to which I have already referred, stated that the intercellular substance can be homogeneous, granular or fibrillar. A. Fuchs [20] mentioned a reddish, intracellular substance that one often finds in a beginning sarcoma. Certain it is that only in necrotic cases of sarcoma does one find an extensive fibrosis present. G. Schappert-Kimmyser and A. W. Mulock Houwer [21]

20. Fuchs, A.: Sympathisierende Entzündung und Sarkom in einem Auge, Verhandl. d. ausserord. Tag. d. ophth. Gesellsch., Wien, 1921, p. 125.

21. Schappert-Kimmyser, J., and Mulock Houwer, A. W.: Melanome und kleinste Sarkome, Arch. f. Augenh. **100-101**:21, 1929.

were the only writers to describe the presence of many collagen fibers without extensive necrosis as more suggestive of a nevus than of a sarcoma. This, too, has been my experience.

Kromayer [12] and Judalewitsch [13] thought this regressive production of connective tissue fibrils to be due to the desmoplastic nevus cells. However, this production of fibrous tissue may be in response to the irritation produced by cytolysis of pigment cells.

The other feature is the striking picture presented by the reaction of the elastic tissue to the tumor growth.

Borst [22] stated that elastic tissue is very resistant to infiltration by a new growth. In a lung that has become almost solid by the invasion of a new growth, one can still see the elastic rings of the smaller bronchi. Wolfrum,[23] writing on nevi of the conjunctiva, mentioned that the elastic fibers about the periphery of the nevus become more wavy and pressed together, often increasing in heaps and in coils, though paler staining and not sharply defined. Within the nevus itself, little elastic tissue is present. Wolfrum quoted Unna who had made similar observations previously in nevi of the skin. Unna believed this disappearance of elastic tissue to be due to a pressure atrophy; Wolfrum thought it caused by the histolytic activity of the nevus cells.

In the present case, too, there was some compression of elastic fibrils at the periphery. In the tumor area itself some small broken elastic fibrils were present. The larger elastic fibrils could be seen to continue, with but little destruction, through the whole length of the tumor and to bulge apart widely due to the densely packed, pigment-filled cells.

This striking reaction of the resistant elastic fibrils to the growth of benign intra-ocular melanoma has so far not been described in the ophthalmic literature.

It is, I think, of interest and of diagnostic importance. It necessarily indicates not that the tumor was made up of a single proliferating focus, the cells of which would tend to push the elastic fibrils away, if resistant, in the form of concentric compressed bands, but rather that one is here dealing with a tumor that presented various foci of proliferation, thus causing the individual elastic bands to bulge widely apart from each other in the tumor itself, with subsequent compression of fibrils about the periphery. These foci of proliferation may be stimulated into activity by the proliferating cells at the center of the tumor and may thus simulate the infiltrative character of malignant growth.

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22. Borst, Max: Die Lehre von den Geschwülsten, Wiesbaden, J. F. Bergmann, 1902, vol. 1, p. 55a.

23. Wolfrum, M.: Der Naevus der Bindehaut, des Augapfels und der Aderhaut und seine Beziehungen zu den melanotischen Tumoren: Ein Beitrag zu der Lehre von der Geschwülstzentwicklung am Auge, Arch. f. Ophth. **71**:195, 1909.

It is impossible to state with certainty how long the nevus had been present in the ciliary body. Though most authors believe that nevi are congenital pigment anomalies, it is also generally agreed that they can originate during adult life. This is especially noted in nevi of the skin.

It seems, at first, problematic whether the injury and subsequent phthisis bulbi had any influence on the development of the nevus. Leber and Krahnstöver [24] found only one of 200,000 eye cases in which a primary sarcoma occurred in an eye already atrophic from other causes, so that they concluded that trauma and chronic inflammation were not predisposing factors. Prof. J. Meller [25] found one case of a beginning sarcoma in an already atrophic eye among several hundred eyes that he had histologically investigated.

Can one draw any analogy between this and the production of nevi? That chronic inflammation exercises some influence on the proliferation of pigment epithelium is well proved by the common occurrence of retinal pigment epithelium proliferation in association with a chronic choroiditis (Parsons [26]). The young cells are at first round, with round or oval nuclei, and are devoid of pigment. According to Krückmann,[27] only these cells are actively ameboid. When the lamina of Bruck is broken, these cells penetrate into the stroma of the choroid and there proliferate. The polymorphism that these epithelial cells can undergo has already been sufficiently emphasized to enable one to accept this possible explanation of the presence of an increased number of typical spindle-shaped melanoblasts in the stroma of the choroid or of the ciliary body.

Another probable explanation is that the cell damage and products of the chronic inflammation had activated the metabolism of the melanoblasts already present to an overproduction of pigment, implying a catalytic action of the disintegrated protein on the oxydase. This excessive pigment production was not confined to the nevus in the ciliary body, but was evident as well in the pigment epithelium of the iris, ciliary body and retina.

Wieting and Hundi traced the proliferative activity of the cell to this overproduction of pigment. The pigment can be regarded as a

24. Leber, T., and Krahnstöver, A.: Ueber die bei Aderhautsarkomen vorkommende Phthisis des Augapfels und über die Bedeutung von Verletzungen bei der Entstehung dieser Geschwülste, Arch. f. Ophth. **45**:164 and 231, 1898.

25. Meller, J.: Kleines Aderhautsarkom in einem nach perforierender Verletzung atrophisch gewesenen Auge, Centralbl. f. prakt. Augenh., July-August, 1916, p. 108.

26. Parsons, J. Herbert: The Pathology of the Eye, London, Hodder & Stoughton, 1905, p. 449.

27. Krückmann, E.: Die pathologischen Veränderungen der retinalen Pigmentepithelzellen, Arch. f. Ophth. **48**:237, 1899.

chemical irritant, so that a vicious circle is established. One has here also a possible explanation, in this overproduction of pigment, for the chronic irritation present in the eye described and probably affecting the other eye. It speaks much for the stability of the melanoblast that melanomas are not more frequent.

I believe that one can reasonably conclude that some relationship certainly exists between chronic inflammation and the formation of melanomas in the ciliary body.

THE CIRCULATION OF THE AQUEOUS

I. RATE OF FLOW *

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The problem of the circulation of the aqueous has been recognized for two generations as crucial to an understanding of glaucoma. Clearly, if the aqueous continually enters the interior of the eye in one region, and is continually reabsorbed from the interior of the eye in another anatomic region, then obstruction to the transit of fluid from source to exit, or obstruction to the outflow at the exit, must be considered among the possible causes of a rise of intra-ocular tension. Equally clearly, if no through and through circulation of the aqueous exists, then obstructive theories of glaucoma are untenable. The importance of this issue not merely for the satisfaction of an academic striving for new knowledge, but also for the discovery of a rational mode of therapy for glaucoma, has led to innumerable and extensive investigations in this field.

The volume of literature on this subject is so enormous that a complete review lies far beyond the bounds of the present paper. However, the effort will be made to present the main trends of modern thought in this field. The concept of the circulation of the aqueous was first advanced two generations ago [1] and is still strongly supported by what has come to be called the "Leber school." The concept of the stagnant aqueous was first advanced by Hamburger [2] as the result of studies which he had undertaken under the direction of Ehrlich. For many years the arguments and experiments that Hamburger advanced received scanty attention, but in the last ten or fifteen years an increasing number of experimenters have become convinced of the truth of Hamburger's

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1. Leber, T.: Die Cirkulations und Ernährungsverhältnisse des Auges, in Graefe-Saemisch: Handbuch der gesamten Augenheilkunde, Leipzig, Wilhelm Englemann, 1903.

2. Hamburger, Carl: Ueber die Ernährung des Auges, Leipzig, Georg Thieme, 1914.

contention. Among the adherents of the theory of the circulating aqueous, there are those who believe that all forms of glaucoma are due to obstruction to the circulation. Others, including ourselves, are convinced that obstruction to the circulation is only one of several factors, the relative importance of which is different in different types of glaucoma. The discovery of some of these nonobstructive factors in the etiology of glaucoma we owe mainly to the critique that has been directed against the circulation theory.

All workers in the field appear to be agreed that if the aqueous does actually circulate, its chief source is in the ciliary body, from which it enters the posterior chamber by a process of secretion (?), ultrafiltration (?) or dialysis (?). The reabsorption of the aqueous has been regarded by most as mainly the function of Schlemm's canal, but the iris and cornea have also been seriously considered. Following Priestley Smith,[3] a small rôle in absorption of fluid is generally assigned to the retina and optic disk, though, so far as we can discover, Smith's interesting observations on enucleated eyes have not been repeated or extended by any subsequent investigators. These questions as to the source and modes of formation of the aqueous, the portals of exit and modes of escape will be dealt with in subsequent papers of this series. For the present, we wish to confine ourselves solely to the question as to whether or not there exists a through and through circulation of aqueous, as distinguished from a closed thermal circulation on the one hand and a random diffusion on the other. We shall assume that, if such a circulation exists, the main source lies behind and the main exit lies in front of the pupil. It must be emphasized at the outset that the existence of a definite through and through circulation would in no way conflict with a to and fro osmotic exchange of fluid and dissolved substances which may be supposed to take place throughout the whole intra-ocular capillary bed.

DOES A CIRCULATION OF THE AQUEOUS EXIST?

The argument for the circulation of the aqueous may be stated as follows:

1. Substances injected into the vitreous, whether in true solution or as suspensions, appear in the anterior chamber within a short time (contradicted by Weiss,[4] Hamburger;[2] confirmed by Nuel and Benoit,[5]

3. Smith, Priestley: On the Escape of Fluid from the Aqueous and Vitreous Chambers Under Different Pressures, Ophth. Rev. **7**:193, 1888.

4. Weiss, O.: Die Ernährung und Zirkulation des Auges, in Nagel: Handbuch der Physiologie der Menschen, Braunschweig, Vieweg & Sons, 1905.

5. Nuel, J. P., and Benoit, F.: Voies d'élimination des liquides intra-oculaires hors de la chambre antérieure et fond de l'oeil, Arch. d'opht. **20**:161, 1900.

Gifford,[6] Knies,[7] Ulbrich,[8] Abelsdorff and Wessely[9]). When experiments of this form are performed with dye stuffs such as fluorescein, the first appearance of the dye can be clearly seen at the pupillary margin. Such phenomena have been pointed to as the visible evidence of a through and through circulation. Against this interpretation, it has been argued that diffusible substances might reach the anterior chamber by pure diffusion, and, in fact, do so even in enucleated eyes. Particles in a suspension, on the other hand, are rapidly phagocytosed by wandering cells which are capable by amoeboid movement of reaching the anterior chamber even in the absence of a current.

Against these objections, it must be pointed out that the rate of diffusion from one chamber into another depends, other things being equal, on the cross-section of the aperture connecting the two chambers. In the eye this aperture consists only in the film of fluid which lies between the iris and lens. The cross-section of this film at the pupillary margin yields an area so small that no appreciable amounts of diffusing substances could be expected to come through it in many hours. Fluorescein injected into the vitreous of a living rabbit's eye appears at the pupillary margin within about half an hour. When injected into the vitreous of an enucleated rabbit's eye kept at 37 C., the dye does not appear in the anterior chamber for many hours and, in fact, as we have found, makes its first appearance as a diffuse staining of the whole iris.

Precisely the same argument can be advanced against the notion that particulate matter injected into the vitreous is carried into the anterior chamber merely by the random amoeboid movement of phagocytes. In a series of experiments performed by one of us (Dr. Friedenwald) directed toward the study of intra-ocular inflammatory reactions, a 1 per cent solution of trypan blue was injected into the vitreous of rabbits' eyes. This substance calls forth a considerable infiltration of monocytes which take up the dye and, twenty-four hours after the injection, can be seen with the corneal microscope floating in the anterior chamber. By carefully studying these eyes with the corneal microscope, it is frequently possible to see these wandering cells enter the anterior chamber at the margin of the pupil. When this happens, one does not

6. Gifford, H.: Ueber die Lymphströme des Auges, Arch. f. Augenh. **16**:421, 1885-1886; **26**:308, 1893-1894.

7. Knies: Ueber die Ernährung des Auges und die Abflusswege der intraokulären Flüssigkeiten, Arch. f. Augenh. **7**:320, 1878.

8. Ulbrich, H.: Klinische Beobachtungen über die Drukverhältnisse in der vorderen und hinteren Augenkammer, Arch. f. Augenh. **60**:283, 1908.

9. Abelsdorff, G., and Wessely, K.: Vergleichend-physiologische Untersuchungen über den Flüssigkeitswechsel des Auges in Wirbethierreihe, Arch. f. Augenh. **64**:65, 1909.

see the wandering cell creep cautiously over the margin of the iris. On the contrary, the cells enter the anterior chamber with quite a spurt and, within one or two seconds, usually travel a millimeter or more before their motion slows down to the much more sedate pace of the familiar thermal circulation.[10]

2. A second line of reasoning in regard to the circulation of the aqueous, closely related to that just stated, has to do with the appearance of wandering cells and implantation metastases in the anterior chamber secondary to inflammatory lesions and tumors of the posterior part of the eyeball. At times the entrance of these cells into the anterior chamber can be observed with the corneal microscope to be characterized by the same initial spurt that was found in the experiments just reported. Critics of the circulation theory admit that a through and through circulation does exist in these instances, but point to the abnormal condition under which the circulation was observed and question the validity of these observations on pathologic eyes for the interpretation of normal conditions.

This criticism cannot, of course, be denied, but it must be pointed out that the same criticism, rigorously applied, would rob us of all information of the outside world, for no phenomenon can be precisely the same when isolated and subjected to observation as it is in its natural unobserved state. This will apply a fortiori to the whole realm of experimental science and is in the nature of a constant warning against the acceptance of conclusions based on only a single set of observations. When, however, a phenomenon is observed consistently under a wide variety of different disturbing conditions, and when, as in our present case, the phenomenon has been observed in many eyes with normal intra-ocular tension, without evidence of vascular congestion and without any turbidity of the aqueous (indicating no change in the permeability of the intra-ocular vessels), then considerable weight must be given to the evidence from this source.

3. The third body of data from which evidence has been adduced in support of the circulation theory consists in the domain of secondary glaucoma, many forms of which appear to be obstructive in origin. Here we must distinguish between a variety of different forms.

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10. If one takes the linear velocity of the flow through the pupil as of the order of 1 mm. per second, as indicated by this observation, and combines this with the estimate to be given below of 1 c.mm. per minute for the volume of flow, one arrives at the value of 1/60 sq. mm. for the area of cross-section of the channels connecting the posterior with the anterior chamber. Assuming that these channels are 70 in number, corresponding to the furroughs on the posterior surface of the iris, and triangular in shape, their dimensions would be of the order of 20 by 20 microns, an estimate which accords well with the histologic facts.

(*a*) *Glaucoma secondary to perforating wounds of the cornea* with adhesion between the iris and cornea constitutes an established clinical fact. Modern writers who disparage the importance of mechanical factors in this form of glaucoma brush lightly aside the classic studies (Fuchs,[11] Priestley Smith[12]) in which it was shown that the synechia precedes the glaucoma, and that the severity of the glaucoma is closely correlated with the extent of the adhesions. The question may here be left open as to whether the occluded outflow channels are in the iris or Schlemm's canal or both. Occasional cases are undoubtedly seen in which extensive adhesions are found without glaucoma. These, however, are the exceptions, not the rule, and require special explanation.[13] As against these detailed studies, the critics of the circulation theory offer the following series of hypotheses (Magitot[14]) for which no experimental evidence has been advanced: That the adhesion of the iris to the cornea causes a vasomotor reflex within the eye; that this vasomotor reflex comes on not during the early period following a corneal wound during which pericorneal congestion and other evidences of vasomotor reactions are in evidence, but later when, to all external evidence, the intra-ocular vasomotor system has returned to normal; that such a vasomotor reflex is capable of causing a permanent rise in intra-ocular pressure, and that an iridectomy inhibits this vasomotor reflex.

(*b*) *Glaucoma secondary to seclusion of the pupil with iris bombé* is an undoubted clinical fact. It has been suggested in this connection also that the adhesions of the iris to the lens disturb the intra-ocular vasomotor balance. Much has been made of the exceptional cases in which, in spite of apparent complete seclusion of the pupil, no abnormal rise of intra-ocular tension is observed. In some of these exceptional cases, atrophic and degenerative changes are found in the ciliary body. In the remainder, it is impossible to exclude the existence of some small patent channel between the posterior and anterior chambers. In regard to the hypothetical vasomotor reflex, the same questions arise as were enumerated in the preceding paragraph.

(*c*) The most obviously mechanical form of *glaucoma* is that *due to dislocation of the lens* into the anterior chamber. Here again the vasomotor reflex has been supposed to exist. It must be admitted that eyes suffering from this form of glaucoma are generally congested and

11. Fuchs, E.: Vordere Synechia und Hypertonie, Arch. f. Ophth. **69**:254, 1909.

12. Smith, Priestley: Glaucoma, London, J. & A. Churchill, 1879.

13. In a subsequent paper the problem of how much of the filtration angle can be obstructed without causing a pathologic rise of tension will be dealt with.

14. Magitot, A.: La symptomatologie du glaucome et le problème pathogénique, Ann. d'ocul. **166**:356, 1929.

painful in contradistinction to the two previous groups of cases, and that in addition to the mechanical factors, a vasomotor factor must be considered. Whether this vasomotor disturbance raises or lowers the intra-ocular pressure, whether it is due to the mechanical irritation of the anterior surface of the iris, or whether it is connected with the extraordinarily sudden onset of increased pressure in these cases remains as yet obscure. We shall report herein an instance of this type in which the vasomotor factor was clearly lacking.

4. The factors concerned in the control of intra-ocular pressure in *uveitis* are still too obscure to contribute much to our knowledge of the present subject. On the side of the purely mechanical factors, we have in some cases the accumulation of wandering cells and débris within the filtration angle (von Hippel[15]). It seems very doubtful, however, whether such deposits have a significant effect on intra-ocular pressure, for they are seen equally often in uveitis without glaucoma. Certainly in these cases the vasomotor factor is of great importance. There is often edema and congestion of the intra-ocular tissues. The protein content of the aqueous is increased, indicating an increased permeability of some of the intra-ocular capillaries, and producing a decrease in the protein osmotic pressure difference between the blood and the intra-ocular fluid. All these factors must combine to increase the rate of formation of intra-ocular fluid, or, more correctly, the balance between the inflow and outflow of aqueous would be expected to establish itself at a higher pressure than in normal eyes. Yet the paradoxical fact remains that many instances of uveitis with congestion and edema of the intra-ocular tissues, with increased protein content of the intra-ocular fluid, have normal or subnormal intra-ocular pressure. Either the vasomotor factor alone is not sufficient to raise the intra-ocular pressure above its normal level, or some subtle differences must exist between the character of the vasomotor disturbance in uveitis with glaucoma from that of uveitis without glaucoma.[16]

5. Concerning the other forms of glaucoma, both primary and secondary, our knowledge is as yet too limited to be used as evidence for or against the theories of the circulation of the aqueous. Rather do these conditions pose the main problems which our theories and investigations aim to elucidate. For the sake of completeness, however, a brief discussion of these will be included. In glaucoma due to hypermature cataract and to dislocation of the lens into the vitreous, the vasomotor factors are certainly of the greatest importance. On section,

15. von Hippel, E.: Zur pathologischen Anatomie des Glaukoms, nebst Bemerkungen ueber Netzhautpigmentierung vom Glaskörperraum aus, Arch. f. Ophth. **52**:498, 1901.

16. This subject will be dealt with in a subsequent paper in this series.

the ocular cavities and tissue spaces in these cases are found to be filled with serous fluid. The vessels are usually dilated, and clinical signs of congestion are usually obvious. On the other hand, these same conditions (hypermature and dislocated lenses) associated with nearly identical signs of intra-ocular vasomotor disturbance may exhibit hypotension and even detachment of the retina instead of hypertension.

We have, elsewhere, brought together evidence showing that in primary acute glaucoma and in acute exacerbations of chronic glaucoma there exists a vascular reaction in the ciliary body characterized by dilatation and increased permeability of the capillary walls. The steps by which this leads to increased intra-ocular tension have been analyzed, but it has been shown that to produce a glaucomatous attack the vasomotor reactions must be confined to the ciliary body; similar reactions in the iris and in the episcleral vessels, and presumably also in the vessels connected with Schlemm's canal, lead to hypotension. Furthermore, a permanent rise of tension was found only in those instances in which the vasomotor crisis in the ciliary body resulted in sufficient edema of that organ to cause it to encroach on the filtration angle. Here we see perhaps in clearest outlines the fact that intra-ocular congestion with increased permeability of the capillaries is not sufficient to cause more than a transitory rise in intra-ocular tension.

Chronic simple glaucoma remains as yet the hub of our mystery, and must continue to be so until an adequate explanation of the shallow anterior chamber in this condition has been supplied.

THE STAGNATION HYPOTHESIS

We have, thus far, presented a summary of what appear to us to be the main lines of argument in favor of the existence of a circulation of the aqueous together with an analysis of the main criticisms that have been advanced against these arguments. It remains to present the positive arguments that have been advanced in favor of the conception of the stagnant aqueous.

1. Historically, the foundation of this theory rests on the so-called Ehrlich[17] fluorescein experiment. The facts in this regard have been determined beyond dispute, but since their interpretation is still debated, and since the phenomenon is one that has elicited recurrent investigation down to the very present, a detailed analysis seems worth while. Ehrlich discovered that when fluorescein (in the form of its sodium salt) is injected intravenously into a rabbit, the dye promptly appears in the aqueous. Modern studies have shown that the first step in the appearance of the dye consists in a staining of the walls of the vessels

17. Ehrlich, P.: Ueber provocierte Fluorescenzerscheinungen am Auge, Berl. klin. Wchnschr. **19**:388, 1882.

in the iris and ciliary body. Thereafter, the stroma of the iris and ciliary body become stained, and finally a green cloud is seen over the surface of the iris. Only with large doses and after a considerable lapse of time does the dye appear in the posterior chamber (unless the intra-ocular vascular balance is artificially upset). Accompanying the appearance of the dye over the surface of the iris, a vertical green streak appears in the aqueous (in rabbits but not in all other animals). The significance of this "Ehrlich line" has been much disputed, but opinion has finally settled on the thermal circulation of the aqueous as its probable cause (van der Heydt [18]).

The concentration of fluorescein finally attained in the aqueous is far below that of the blood, but this difference has been accounted for with mathematical precision by considering the effect of the proteins in the blood serum in "binding" a large part of the dye. Actually, the concentration of free diffusible dye in the aqueous and the blood has been found equal.[19] Finally, if the aqueous is withdrawn and "plasmoid aqueous" is allowed to form, this aqueous of second formation is found to come in the main from the ciliary body, and to contain a much higher concentration of fluorescein, strictly in accord with its higher protein content.

These findings have been taken to signify [20] (*a*) that there is normally no formation of aqueous from the ciliary body, (b) that the ciliary epithelium is impermeable to fluorescein, (*c*) that the aqueous is formed exclusively by diffusion from the intra-ocular vessels, mainly those of the iris. Now it must be clear that if (*b*) is true, then conclusions (*a*) and (*c*) cannot be drawn from the experiment, for if the ciliary barrier is impermeable to fluorescein, then fluorescein would fail to appear in the posterior chamber no matter whether or not water was filtering through the same barrier. As a matter of fact, the barrier is not impermeable to fluorescein, for with sufficiently large dosage and sufficient time the dye does appear in the posterior chamber. Its delayed appearance here can be attributed to the fact that in reaching the anterior chamber the dye need diffuse only through the endothelium of the blood vessels and the minimal stroma of the iris, while to reach the posterior chamber, it must pass not only capillary endothelium and the denser stroma of the ciliary body, but also the epithelium.

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18. van der Heydt: Thermal Current in the Anterior Chamber, Am. J. Ophth. **6**:822, 1923.

19. Wessely: Ergebn. d. Physiol. **4**:566, 1905. Yoshida, Y.: Ueber Wechselbeziehungen zwischen Blut und Kammerwasser, Arch. f. Augenh. **100-101**: 470, 1929. Hertel: Ueber die Bedeutung der Ehrlichscher Fluoresgeinversuche, ibid. **100-101**:460, 1929.

20. Fischer, F. P.: Ueber die Permeabilität der Hornhaut und über Vitalfärbungen des vorderen Bulbusabschnittes mit Bermerkungen über die Vitalfärbung des Plexus chorioideus, Arch. f. Augenh. **100-101**:480, 1929.

Considered in this light, we see that there is no necessary connection between the appearance of fluorescein in the aqueous and the existence or absence of a constant flow of fluid. Fluorescein reaches the aqueous by virtue of its diffusion pressure which must be the same in all vessels. It must, therefore, reach the aqueous first at that point where the barrier to its diffusion is thinnest or most permeable, altogether uninfluenced by the hydrostatic pressure within the vessel. On the other hand, the intra-ocular fluid circulation, if it exists, must depend on the existence of a difference in hydrostatic pressure in different capillary beds within the eye.

An illustration of the irrelevance of such diffusion phenomenon for a study of capillary pressure is to be found in the recent work of Rous, Gilding and Smith,[21] who showed that dye stuffs injected intravenously appear in the perivascular tissues first at the venous ends of the capillaries. Since the osmotic transfer of water across a membrane is, in general, accompanied by an escape of diffusible substances in the opposite direction, it might be expected that in the Ehrlich experiment and in the Rous experiment the escape of dyestuffs from the blood vessels will occur most rapidly in those portions of the vascular tree in which reabsorption of fluid was taking place. Such an argument, however, neglects the wide variations in permeability which probably exist in different parts of the vascular tree.

2. If fluorescein solution is injected into the "posterior chamber" of the eye of an albino rabbit, the green color can be seen as a crescent behind the iris. Often from twenty to thirty minutes may elapse before some of the dye escapes into the anterior chamber. This experiment, first performed by Hamburger [2] and repeated by numerous observers, has been interpreted as proving that there is a physiologic seclusion of the pupil, i. e., that the contact between iris and lens with the undilated pupil is water-tight.

While there can be no doubt as to the facts observed, considerable doubt exists as to exactly where the fluorescein was first injected. We have performed a slight variation on this experiment with totally different result. We injected minute amounts of the dye directly into the ciliary body instead of into the posterior chamber. In albino rabbits, the sharp outlines of the initial droplet of dye can be clearly seen. Within a minute or two, these outlines become blurred and streamers of color can be seen extending into the posterior chamber. The further course of these streamers in a radial direction along the posterior surface of the iris to the pupillary margin and into the anterior chamber is seen to take place in a steady movement without a moment's hesita-

21. Rous, P.; Gilding, H. P., and Smith, F.: The Gradient of Vascular Permeability, J. Exper. Med. **51**:807, 1930.

tion. The dye arrives in the anterior chamber from three to five minutes after its injection into the ciliary body. The delay in Hamburger's experiments cannot, therefore, be attributed to a seclusion of the pupil. A probable explanation of the apparent contradiction in these two sets of experiments is to be found in the extreme shallowness of the posterior chamber in the rabbit's eye, so that the injection by Hamburger's method probably goes into the zonula and anterior vitreous rather than into the posterior chamber.

3. In the discussion of our problem, the feature to which the largest bulk of literature has been devoted concerns the function and mode of operation of Schlemm's canal. Those who support the theory of the stagnant aqueous assert that the canal plays a rôle no different from that of any other venous channel within the eye, across the walls of which an osmotic exchange may take place. As experimental approach to the problem, all manner of substances, diffusible, colloid and particulate, have been injected into the anterior chamber, and their subsequent course observed. In general, it has been found that diffusible substances and colloids of small micellar size appear promptly in those episcleral vessels connected with Schlemm's canal, while large colloidal micelles and visible particles accumulate in the spaces about the iris and anterior ciliary veins and about the anterior perforating vessels.

The interpretation of these findings involves two separate questions: What is the relative importance of the canal and of the veins of the iris in the reabsorption of aqueous? How do colloids and solid particles escape from the ocular cavity which, all other evidence tends to show, is separated from the blood stream by a membrane impermeable to colloids and solid particles. Definite answers to either of these questions cannot be given in the present state of our knowledge, nor are these answers necessary for the present argument, it being sufficient for the current conception of the circulation of the aqueous to determine that absorption from the anterior chamber does take place. In this regard, the absorption of fluid injected into the anterior chamber at pressures only slightly above the normal level is more cogent than the course of foreign matter which may be influenced by diffusion or phagocytosis.

4. A more powerful argument for the stagnation of the aqueous than any so far considered arises from modern studies on the chemical composition of the ocular fluids. Within the limits of error of the experiments, the composition of the aqueous approaches that of a dialysate of the blood plasma rather than that of a filtrate of the blood plasma. The difference in osmotic pressure between the blood and the plasma corresponds to the presumed excess of intra-ocular capillary blood pressure over the intra-ocular pressure. The difference in electrical potential between the blood and the aqueous is of the sign and general

order required for thermodynamic equilibrium between the blood and the aqueous.[22] All of these phenomena receive a simple explanation if one assumes (*a*) that the aqueous is stagnant and (*b*) that the blood-aqueous barrier is a simple semipermeable membrane. Strictly speaking, neither of these assumptions is proved by the experimental results. All that one can legitimately conclude from these experiments is (*a*) that the flow of aqueous, if it exists, is slow compared with the diffusion of crystalloids into the ocular fluids, and (*b*) either that the cellular barrier between the blood and the aqueous behaves toward water and the crystalloid components of the blood as if it were an inert semipermeable membrane, or, that any force which this cellular barrier exerts in enhancing or retarding the diffusion of these substances from the blood to the aqueous or in the reverse direction is exerted to an approximately equal degree on all the component elements of the aqueous.

The second of these conclusions is not particularly germaine to the present discussion. For the purposes of a first approximation to the problem, we shall continue to treat the blood-aqueous barrier as if it were an inert semipermeable membrane, leaving the qualifications and corrections of this statement for a more detailed analysis later. The conclusion that the flow of the aqueous, if it exists, is small compared with the diffusion of crystalloids into the ocular fluids, is one to which it is difficult to give quantitative meaning except in the crudest sense. Since, however, the existing data have been interpreted by some to prove that the aqueous is stagnant, and since the validity of any measured rate of circulation of the aqueous rests, in part at least, on the compatability of the determined rate of flow with the known facts regarding the chemistry of the aqueous, therefore the attempt will be made to estimate, however crudely, what limits these chemical facts put on the possible rate of flow of the fluid.

First, we must find some way to estimate how much time is required for the aqueous to come into equilibrium with the blood by diffusion alone. Duke-Elder [23] showed that when hypertonic solutions are injected intravenously, the intra-ocular pressure falls. Unless the pressure reaches zero, it should continue to fall until osmotic equilibrium between the blood and the aqueous has been reestablished. The duration of the fall may, therefore, be taken as a rough measure of the time required for the reestablishment of osmotic equilibrium. This time in Duke-

22. Duke-Elder, W. S.: The Nature of the Intraocular Fluids, Brit. J. Ophth., 1927, vol. 11, monograph supp. III. Hertel, E.: Ueber Flüssigkeitsbewegungen im Auge, Deutsche Ophth. Gesellsch. **48**:152, 1928. Salit, P. W.: The Biochemistry of the Aqueous Lens and Vitreous, Arch. Ophth. **4**:374, 1930.

23. Duke-Elder, W. S.: Reaction of Intraocular Pressure to Osmotic Variation in Blood, Brit. J. Ophth. **10**:1, 1926.

Elder's curves lies between forty and eighty minutes. It should be noted that the magnitude of the osmotic disturbance created in these experiments is considerably greater than the differences in concentration between a filtrate and a dialysate of the blood.[24]

Adler [25] followed the course of aqueous dextrose concentration in comparison with blood dextrose concentration following the intravenous injection of dextrose solution. He found a lag of fifteen minutes between the peak of the aqueous dextrose curve and that of the blood dextrose curve. Similar values are found by Kronfeld [26] for the establishment of bicarbonate equilibrium between the blood and aqueous. The good agreement between these two widely diverging methods of computation makes it fair to assume that equilibrium in concentration between blood and aqueous can be expected to take place by diffusion and osmotic exchange within about one hour. If, therefore, the aqueous were formed by filtration at such a rate that the total volume of fluid was replenished in not less than five to ten hours, then the deficiency in its constitution caused by its circulation as against the expected constitution of a stagnant dialysate would be less than the experimental error of these chemical measurements.

A further correction, however, must be made which gives us even more latitude. Up to the present we have made no assumptions regarding the mechanism of reabsorption of the aqueous. There are, however, good grounds for believing that the aqueous does not simply trickle out of the anterior chamber by hydrostatic pressure, but is reabsorbed into the blood stream in virtue of the osmotic pressure of the plasma proteins in the venules of the iris and Schlemm's canal. Now it is well known when fluid is transferred across a membrane by osmotic pressure, diffusible substances tend to cross the membrane in the opposite direction. The forces concerned here are precisely the same as those that tend toward equilibrium in dialysis. The composition of the fluid remaining in the anterior chamber must, therefore, approach that which is expected on stagnation and dialysis, and on even the moderately slow

24. In a typical experiment, Duke-Elder injected 15 cc. of 30 per cent saline solution intravenously into a cat weighing 3,600 Gm. Assuming the blood to be one tenth of the body weight, this animal had 360 cc. of blood, which would contain approximately 3 Gm. of salt. To this is added 15 cc. containing 5 Gm., resulting in a momentary increase in salt content of over 150 per cent. Even assuming that a rapid exchange of salt and water takes place between the blood and the tissues, this figure remains large compared with 25 per cent as the maximum expected difference in concentration between a filtrate and a dialysate of the blood.

25. Adler, F. H.: Investigation of Sugar Content of Ocular Fluids Under Normal Conditions, and Glycolytic Activity of Tissues of Eye, Tr. Am. Ophth. Soc. **28**:307, 1930.

26. Kronfeld, P.: Die Kohlensäuregehalt des Kammerwassers, Arch. f. Ophth. **118**:606, 1927.

circulation which we have postulated the aqueous must be chemically indistinguishable from a dialysate, providing, of course, that the blood-aqueous barrier remains an inert semipermeable membrane.

RATE OF FLOW

The foregoing discussion has seemed to us sufficient to prove the existence of a through and through circulation of the aqueous, and to set some rather ill-defined limits to its magnitude. For an understanding of the relation of this flow of fluid to the physiology of intra-ocular pressure, it would be most desirable to know more definitely the order of magnitude of the normal circulation. We have, therefore, attempted to measure this rate of flow in experimental animals.

There have been numerous previous attempts to measure the rate of flow of the aqueous. Unfortunately, none of these are wholly free from criticism. The first attempt consisted in puncturing the anterior chamber and measuring the rate at which fluid dripped out of the eye.[27] Estimates of the order of 50 c.mm. per minute were obtained in this way. Obviously, however, the rate measured is not the normal rate of circulation, but rather the rate at which fluid exudes from the intra-ocular vessels when the supporting counterpressure of the normal intra-ocular pressure is withdrawn.

In order to avoid this difficulty, the effort was later made to measure the flow at normal intra-ocular pressure. The experiment, as developed by Leber,[1] Priestley Smith[3] and finally Niesnamoff,[28] consists in inserting into the anterior chamber a cannula connected with a movable reservoir of salt solution. A horizontal tube of small internal bore, containing an air bubble, is between the eye and the reservoir. The position of the reservoir is first adjusted until the position of the bubble becomes stationary, the normal intra-ocular tension being reestablished. The animal is then killed without disturbing the eye. As soon as the blood pressure falls, fluid begins to run into the eye from the reservoir, at first rapidly to replace the volume of blood lost from the eye, and then at a slow, steady rate. The experiment has been elaborated to measure the rate of flow into or out of the eye at various pressures in living and dead animals. The flow measured in this way on various species was found to lie between 5 and 10 c.mm. per minute. This ingenious experiment, however, fails to withstand criticism, for, while the intra-ocular pressure is maintained at a normal level, the intra-

27. Hovius: De circulari humorumocularium motu, Traj. ad. Rhenum, G. van de Water, 1702. Jesner: Der Humor aqueus in seinen Beziehungen zu Blutdruck und Nervenreizung, Arch. f. d. ges. Physiol. **23**:14, 1880.

28. Niesnamoff, E.: Ueber die quantitativen Verhältnisse der Filtration und Secretion des Kammerwassers, Arch. f. Ophth. **42**:1, 1896.

ocular vascular pressure is not at its normal level. It can readily be shown in performing this experiment on a living animal that the rate of flow of fluid into and out of the eye is just as intimately related to the blood pressure as it is to the intra-ocular pressure. The most that can be concluded from these experiments is that the normal rate of flow is probably less than that determined in this way.

Various efforts have been made to determine the magnitude of the circulation by measuring the period required for the concentration of some foreign substance, dye stuff or protein introduced into the aqueous to be reduced to one-half its original value. The discussion in the previous section, however, justifies the conclusion that the escape of foreign substances from the aqueous must take place under the influence of diffusion pressures totally unrelated to the forces that control the circulation of the intra-ocular fluid.

Uribe-Troncoso [29] attempted to measure the rate of flow by stripping off the bulbar conjunctiva and collecting the serosanguineous fluid that escapes from the episcleral vessels. The total volume of this fluid and the volume of red blood corpuscles in it are measured. After allowing for the amount of plasma normally associated in the blood with that volume of red blood corpuscles, the remaining amount of fluid is considered to be aqueous which has escaped from the eye during the period of the experiment. It has been urged against this procedure that similar results could be obtained were the experiment performed on any other part of the body. Whether or not this vitiates the result might perhaps be debated, but there are two elements in the experiment that would tend to produce some inaccuracy. In order to perform the experiment, Uribe-Troncoso found it necessary to dislocate the eyeball forward, a procedure that must increase the intra-ocular venous pressure on account of the pressure of the lids on the tissues behind the equator of the eye. In the second place, the drainage was measured against zero pressure in the outflow vessels. Both these procedures should tend to make the readings too high; nevertheless, this represents the closest approach to a true measurement of the intra-ocular circulation and gives, we feel, a valid measure of the rate of flow under circumstances that are not far from normal. Uribe-Troncoso's results of from 2 to 3 c.mm. per minute, therefore, probably are not far from the true magnitude.

EXPERIMENTAL WORK

The experiments we are reporting represent a return to the Priestley Smith-Leber-Niesnamoff method in the sense that we have connected the anterior chamber of an animal's eye with a movable reservoir of

29. Uribe-Troncoso, M.: The Physiologic Nature of the Schlemm Canal, Am. J. Ophth. **4**:321, 1921.

salt solution and have recorded the movement of a bubble in a capillary tube between the eye and the reservoir. In the previously recorded experiments, however, either the intra-ocular pressure or the blood pressure was seriously disturbed. In our experiments we have attempted to interfere with both these pressures to the least possible degree. It is obvious that if an eye is connected with a reservoir of fluid (fig. 1, *F*), which is elevated to a level so as to just balance the normal intra-ocular pressure, then there will be no flow of fluid through the cannula (*A*) and no movement of the bubble (*D*). The normal circulation of aqueous continues undisturbed through its normal portals of entry and of exit. If now, we find some method of obstructing the normal outflow channels, then, without any change in the pressure levels we can secure a diversion of the normal stream of fluid out of the eye through our cannula resulting in measurable displacement of the bubble (*D*).

The possibility that the normal outflow channels could be effectively blocked was suggested by the fact that glaucoma has been produced in animals by the injection of various colloid dyes into the anterior chamber. After experimenting with a considerable variety of colloidal solutions and also with very fine grained suspensions, it was discovered that the animals own serum furnished the best means for our purpose.[30] The experimental procedure was as follows:

Two needles (A_1, A_2) were inserted into the anterior chamber of one eye of a dog under paraldehyde anesthesia. The larger of these needles was connected through a capillary tube, which contained a small bubble of air (*D*), to a reservoir of physiologic solution of sodium chloride (*F*). This reservoir was then raised or lowered until the bubble became stationary (except for arterial and respiratory pulsations) and had been maintained stationary for from ten to fifteen minutes, the eye having returned to its normal equilibrium. Without altering the intra-ocular pressure, then, some of the animal's own serum was injected into the anterior chamber through the smaller needle (A_1). During this injection, stopcock B_3 was turned so that the fluid displaced from the eye could escape through the wide bore tubing without disturbing the capillary bubble. As soon as the injection was completed, stopcock B_1 was closed and B_3 turned back to its original position. The position of the bubble in the capillary tube was then recorded from minute to minute, and it was found to move away from the eye at the rate of about 1 c.mm. per minute. Continuous blood pressure tracing was taken in order to ensure the absence of any change in the arterial pressure.

30. The difficulties encountered with substances other than serum may be of interest. Positively charged colloids were most effective in blocking the exits, but were all irritant. Negatively charged colloids were, on the whole, not irritating to the eye, but successfully occluded the outflow channels only after several hours, a period which for other reasons could not be allowed. Of the suspensoids tried, only india ink was effective, but the best commercial preparations of this contain ammonia and camphor. Our efforts to prepare equally fine suspensions of carbon in the absence of these impurities failed completely as soon as salt was introduced into the solution. We were not successful in blocking the outflow with oil as was suggested by Leplat (Ann. d'ocul., 1889, vol. 101).

Before we assume that the value of 1 c.mm. per minute obtained in this experiment is a valid measure of the normal rate of flow of the aqueous, the assumptions underlying this conclusion must be carefully analyzed. These assumptions are: (1) that the anesthetic used does not upset the normal vasomotor equilibrium; (2) that the introduction of needles into the anterior chamber can be accomplished without such an upset; (3) that the serum introduced is nonirritating; (4) that the serum does effectively block the normal portals of outflow, and (5) that the serum does not cause an increased formation of aqueous by the iris.

1. In regard to the anesthetic, it may be said that carefully purified paraldehyde was chosen because it is known to have no appreciable

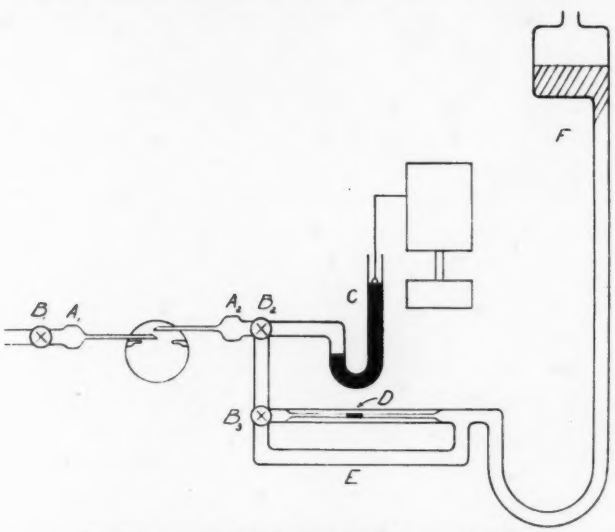

Fig. 1.—Modified Leber bubble manometer.

effect on the blood pressure. The tension of the intact eye of a dog as measured by a tonometer is not influenced by this anesthetic.

2. The introduction of needles into the anterior chamber can only be accomplished by a momentary compression of the eyeball, following which the intra-ocular pressure goes through a period of sharp reaction which can be well followed as one balances the intra-ocular pressure with the movable reservoir. There is usually a primary rise in pressure followed by a fall below normal and then a more gradual rise back to normal. This whole cycle of events, however, takes place within five minutes after which a steady equilibrium is regained and, in a well conducted experiment, if the needles are not further disturbed, the bubble can be maintained in a steady state for upward of one hour.

In addition to the direct effects of the pressure exerted on the eye in introducing the needle, there is the possibility of vasomotor reflexes

produced by trauma to the cornea. The use of very sharp needles and the preliminary instillation of one drop of 1 per cent cocaine minimize these effects. The reaction of the pupil seems a fair index of such effect, and experiments in which marked miosis followed the introduction of the needle were not considered valid. The values obtained for the rate of flow of aqueous in these cases were much higher than those which were found in experiments regarded as satisfactory.

After a needle has been in the anterior chamber for from one to two hours, miosis occurs and the intra-ocular pressure tends to fall. This was attributed to the irritative effect of the needle and for this reason no readings were accepted as valid if the experiment lasted over one hour.

3. In regard to the irritative qualities of the serum, the same criterion of the reaction of the pupil was adopted. By injecting the the serum carefully and slowly at a temperature of 30 C., the anterior chamber can be washed out without producing more than a minor flutter in the pupil.

4. The efficacy of the serum in obstructing the outflow can be attributed to two factors: (*a*) the balancing of the osmotic forces across the wall of Schlemm's canal and (*b*) the reduction in permeability, which occurs in all body membranes when their surfaces are bathed in fluids containing proteins. The degree to which such blocking occurs was tested in each experiment in the following way. After the flow measurements had been made, the reservoir was raised by a given amount and a slight flow into the eye was observed and recorded. The needle was then inserted into the opposite, hitherto intact, eye of the same dog, and the rate of flow into the eye at this same supranormal pressure was measured. A comparison of these two figures indicated that at the same supranormal pressure the presence of serum in the anterior chamber blocked between three fourths and nine tenths of the outflow.

5. It may be argued that the small flow measured was not the normal circulation of aqueous but rather fluid extracted from the capillaries of the iris by the increased osmotic pressure of the aqueous. If it were true, as this argument assumes, that the proteins of the serum in the anterior chamber gradually diffuse into the stroma of the iris and there exert an increasing osmotic attraction, then our experiment should have revealed a slowly rising rate of formation of the fluid. The contrary was the case. In these experiments it was found that, barring changes in the blood pressure and irritative reactions, which we have described, the rate of movement of the bubble out from the eye was remarkably constant over a period of about one hour, at the end of that time, if the experiment was continued further, irritative reaction

began to become manifest in miosis and circumcorneal congestion, and the rate of outflow became irregular and in some instances reversed, the fluid flowing into the eye at an increasing rate.

A further check on this point was obtained by microscopic study of the eyes at the end of some experiments. Without removing the needles from the anterior chamber, but after turning off their stopcocks so that no more fluid could go into or out of the eye, the globe was enucleated and placed in a fixative. On section, the coagulated serum could be seen in the anterior chamber extending through the spaces of Fontana up to the wall of Schlemm's canal, but no coagulum was seen deep in the iris crypts or iris stroma.

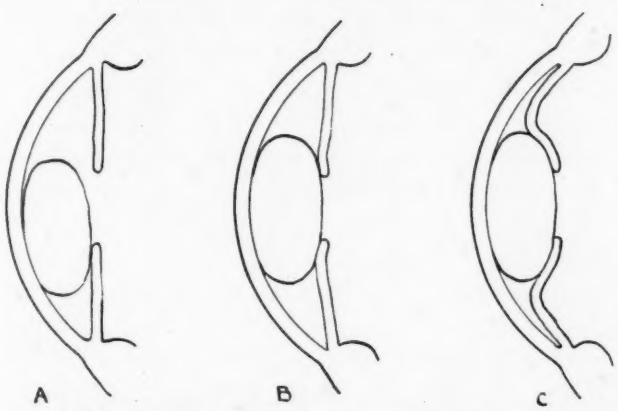

Fig. 2.—Successive positions of the lens in the case reported.

RATE OF FLOW IN A HUMAN EYE

The validity of these experiments may be still further supported by the report of a very extraordinary case which we had the opportunity to study.

The patient was a child with a very mild congenital glaucoma which, after the use of miotics for some years, had become compensated and had maintained a normal intra-ocular pressure without medication and without loss of vision for some time. As an additional anomaly, the lenses were extremely small, measuring only 7 mm. in equatorial diameter. Eventually, the lens became dislocated in one eye, first into the vitreous and then into the anterior chamber. Here it bobbed around like a drop of oil without causing the slightest congestion of the eyeball or change in the intra-ocular pressure. In this condition the child was admitted to the hospital for study prior to an attempt to remove the offending lens. There was no evidence that the presence of the lens in the anterior chamber caused any abnormal vasomotor reactions in the eye.

It was the good fortune of one of us (Dr. Friedenwald) to see this child one day at noon, and to observe that the condition had not changed (fig. 2, *A*). Fifteen minutes later the nurse noted that something peculiar had happened. On reexamination it was found that the lens had slipped up over the pupil and was forming

a sort of ball valve with the iris (fig. 2, *B*). During the next half hour the iris slowly bulged forward around the edge of the lens, and the anterior chamber became evacuated (fig. 2, *C*), but it was not until the iris had approached close to the cornea that the intra-ocular tension began to rise. It was possible subsequently to measure the volume of the anterior chamber in the opposite eye by determining the diameter and curvature of the cornea and estimating its depth with the corneal microscope and an attached scale. Likewise the offending lens was subsequently obtained for measurement. The difference between these two values gives the volume of aqueous trapped in the anterior chamber. About two thirds of this amount of aqueous disappeared from the eye in from thirty to forty-five minutes. From this we could estimate the rate of flow, which was found to be approximately from 1.5 to 2.5 c.mm. per minute, in close agreement with the values obtained in experimental animals.[31]

It remains to be shown that the order of magnitude of the circulation of the aqueous which we have estimated is compatible with the limits arrived at in the previous discussion on the rate of diffusion of substances into the eye. We have estimated that osmotic equilibrium between the blood and the aqueous is achieved within about one hour. The experiments on which this estimate is based were performed on cats, while our measurements were performed on dogs. The total volume of circulating aqueous in these animals, including that in the anterior vitreous, may be estimated as from 0.3 to 0.5 cc. At the rate of flow that we have estimated, this fluid would be replaced every five to eight hours. The rate of flow is, therefore sufficiently slow as compared with the rate of diffusion to enable any deficit in its composition as compared with that expected of a stagnant dialysate to disappear within the limits of accuracy of the chemical measurements.

$$V = \frac{\pi}{3}[Rh^2 + r^2h]$$

in which R is the radius of the sphere, h the altitude of the segment, and r the radius of its base. In our case, $R = 7.5$ mm.; $h = 3$ mm.; $r = 6$ mm. Therefore $V = \frac{\pi}{3} 175.5 = 182.7$ c.mm. The lens in this case had the shape of an elipsoid of revolution, its thickness being 3 mm., equatorial diameter 7 mm. The volume of an elipsoid of revolution is given by the formula

$$V = \frac{4}{3}\pi ab^2$$

in which a and b are the semidiameters. Therefore, $V = \frac{4}{3}\pi$. 18.375 c.mm. = 76.9 c.mm. The difference between these two values is the volume of the entrapped aqueous = 105.8 c.mm. Approximately two thirds of this or 70.5 c.mm. escaped in from thirty to forty-five minutes, giving a flow velocity of from 1.5 to 2.5 c.mm. per minute.

31. The method of computing this value is as follows. The volume of a segment of a sphere is given by the formula

CONCLUSIONS

1. There exists a continuous through and through circulation of aqueous within the eye.

2. The rate of flow in dogs has the order of magnitude of 1 c.mm. per minute.

3. A single estimate in man gave a value of the same order of magnitude for the rate of flow.

4. The chemical composition of the aqueous is compatible with this velocity of flow.

THE PROBLEM OF LATE AFTERNOON LIGHTING*

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There has long been a belief among those who have to face lighting problems in a practical way that the mixture of artificial light and daylight is not desirable. One prominent lighting engineer writes that in making a satisfactory installation to be used as a supplement to daylight, invariably more light has to be planned for than is required in an inside room in which artificial light alone is used. In other cases it has been a question of serious debate whether it is not better and perhaps more economical that daylight be excluded entirely in the late hours of the afternoon and artificial light alone be used. In still other cases photometric measurements of mixtures of artificial light and daylight have been discredited as not having their accustomed meaning because of the belief that these mixtures create a visual anomaly. If space would permit, many other instances could be cited of a similar character. The question has long been under discussion in the lighting of schoolrooms, offices, factories, etc. When a belief has persisted so long in spite of obvious difficulties of acceptance and explanation, it is usually not safe to assume that it is entirely without justifiable cause or foundation. Very often, however, the true cause is found not to be the one popularly assigned. From the standpoint of the composition of the light, it seems incredible that there could be anything especially deleterious to the eye in the mixture of daylight and artificial light. The natural assumption would be that the mixture would be poorer than daylight and better than artificial light. Very few, even of those who hold to the belief that the mixture is deleterious, would rate an illuminant that gives a light intermediate in composition and color between daylight and Mazda light as less desirable than Mazda light; nor could they reasonably hold that it should make any difference so long as the same composition is obtained whether the light waves are mixed in the process of emission or after emission has taken place.

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Four types of reason might perhaps be assigned for the belief. 1. The mixture is itself deleterious. 2. The method of making the mixture is at fault; that is, artificial light usually comes from more or less concentrated overhead sources and the daylight from windows or side sources of large area. 3. The trouble is not with the light or type of installation, but with the state of sensitivity of the eye. For example, during the greater part of the day the eye is desensitized by a high intensity of illumination which becomes very high around midday. As the light fails through the afternoon, the eye's gain in sensitivity by adaptation, if its full efficiency for each intensity of light is to be attained, must keep pace with the loss of light. During the middle and late hours of the afternoon daylight fails more rapidly than the eye adapts; hence, a higher total of light is needed in the late afternoon to give satisfactory seeing than if the eye had not had the hours of pre-exposure to the higher daylight intensities. From this point of view it can be readily understood why it should be found that in case of an installation that is to be used as a supplement to daylight, a higher total intensity has to be planned for than is needed in an installation for an inside room. 4. The belief is based on superficial impressions of various kinds: (*a*) A sudden change either in intensity or in color of light is apt to be unpleasant. (*b*) Artificial light is colored light. Colored light, depending on its hue and saturation, is strong in its subjective effect. For this reason a superficial comparison of colored and colorless light usually results in an overestimation of the amount of the colored light. There is a tendency, therefore, to overestimate artificial light as compared with daylight or a mixture of artificial light and daylight. Unevenness of distribution, unevenness of surface brightness and poor diffusion also frequently lead to the overestimation of artificial light. And (*c*) a low indoor daylight illumination, even when supplemented by a considerable amount of artificial light, seems insufficient when contrasted with the more brightly illuminated exterior seen through the windows. An equally low indoor artificial illumination seems sufficiently intense when contrasted with the darkness of a night exterior.

In order to test the first two of these reasons the following investigation has been conducted. Artificial light and daylight were mixed in equal proportions at different levels of intensity, and a comparison was made of the effect on the eye of these mixtures with that of daylight and of artificial light of the same photometric intensities. Two types of installation were used. In the first the artificial light, the daylight and mixture of the two, all came from the same light-well and all were passed through a diffusion sash of ground glass swung beneath. The distribution effects for the three kinds of light were thus as nearly the

same as was possible. In the second the daylight and the artificial light were obtained from the light-well, and the mixed light was formed from the artificial light coming from the light-well and daylight from side windows. This conformed roughly to the conditions assigned in the second of the aforementioned reasons and gave a closer approximation to the illumination effects under which the mixture is ordinarily used.

In a second series of experiments the artificial light was turned on at different times in the late hours of the afternoon on different days, and the effect on the speed of vision was determined. In these experiments the speed of vision was obtained at intervals of fifteen minutes, beginning early or in the middle of the afternoon and continuing until after darkness was complete. The series was so arranged that the speed was obtained immediately before and after the artificial light was added, the tests then being continued under the mixture of the two lights through the period of vanishing daylight and long enough under the artificial light alone for the eye to become completely adapted to that light, as was shown by the absence of further change in the result. These results gave a history of the eye's performance under the changing intensities of afternoon light until the artificial light was turned on, the immediate effect of adding that light, and the effect from then on until a constant state of performance was reached. An opportunity is thus had to see directly the effect of adding the artificial light on the powers of an eye that has been subjected to the actual conditions under which all of our eyes are placed in the course of a working day which lasts until or after nightfall. It is interesting to note that the speed of vision was increased by the addition of the artificial light in each case to nearly the same value as would be expected for daylight if it were to be made of the same intensity as the mixture produced by adding the artificial light; but it is not equal to the performance given when, as was later tried, the eye was completely adapted to that same amount and proportion of mixture of artificial light and daylight. Quite aside from its bearing on the problem of mixing artificial light with daylight, the results are interesting too with regard to the information they give as to the eye's powers of performance at different times under the changing afternoon illumination, and the opportunity that is afforded thereby for comparing these powers of performance with hourly records of various kinds of industrial production during the afternoon hours for the same season of the year.

In a third series of experiments a brief study of the problem was made in relation to the adaptation of the eye. The object of this study was to show to what extent the eye is rendered deficient in the late hours of the afternoon by its previous exposure to a light of high intensity and by its failure to keep pace by adaptation with the change

of intensity. Two sets of experiments were conducted. In the first set a determination was made of the eye's deficiency in speed at the time the artificial light was added, due to the adaptation situation just noted. That is, the speed was obtained with the eye fully adapted to a mixture of artificial light and daylight of the same intensity and proportions as were used in the afternoon series, and the difference taken between this speed and that obtained in the afternoon series. As a supplement to these results it was determined also what intensity a mixed light of these proportions must have in order to give the speed obtained in the afternoon series when the eye is fully adapted to the illumination employed. The result obtained may be considered the effective value of the illumination used in the afternoon series for the state of adaptation prevailing at that time, and indicates roughly the intensity of illumination that would be needed to give equally good results in an inside room. In the second set of experiments the transition from early afternoon light to artificial light was made abruptly. The intention here was to get some estimate of the total effect of the preexposure of the eye to the higher intensities of daylight on its subsequent powers of performance at the lower levels of intensity used in artificial lighting. In these experiments the eye was exposed for one hour to the daylight intensity, and the speed of vision determined. The daylight was then entirely excluded from the room, and the artificial light turned on. Speed tests were made immediately and at intervals of five minutes until complete readaptation had occurred. The difference in the speed at the beginning and the end of the period under the artificial light shows the full effect of the daylight preexposure. As a supplement to these results, determinations were made of what intensity of light was needed with the eye fully adapted to the artificial light to give each of the speeds obtained while the eye was progressively adapting. As before, each of these values might be roughly designated as the effective value of the illumination employed for that particular state of adaptation, and the difference between it and the illumination actually used, the illumination equivalent to the eye's loss of speed for the particular condition in question.

A COMPARISON OF THE EFFECT OF ARTIFICIAL LIGHT, DAYLIGHT AND MIXTURES OF ARTIFICIAL LIGHT AND DAYLIGHT ON ACUITY, SPEED OF VISION, POWER TO SUSTAIN ACUITY AND OCULAR FATIGUE

The experiments were conducted in an optics room especially fitted for the purpose. This room was 16 feet long, 13 feet wide and 12 feet high. The walls were painted a matt white and the floor a matt light gray. The room was provided with two windows on one side,

3 by 6 feet, and a skylight 12 by 9 feet. Beneath the skylight was a light-well 8 feet deep at one end and 5 feet at the other. The walls of this light-well were painted matt white. Beneath the light-well were swung two diffusion sashes of ground glass, each 12 by 4½ feet. All of the light entering the room from the light-well passed through these sashes. To provide for the ventilation of the room the sashes were dropped 11 inches below the opening of the light-well.

For the artificial light, eight x-ray reflectors[1] (no. 610 Jupiter) were used, equally spaced, 6 feet above the diffusion sashes. They were attached by adjustable mounts to an iron pipe supported on 9 inch brackets extending out from the back wall of the light-well. The design of the reflectors, the height above the diffusion sashes and the adjustable mounts permitted of a comparatively even spray of light over the diffusion sashes. The effect was that of a room uniformly illuminated with a soft diffused light with very little unevenness of surface brightness.

In order to provide for the control and variation of the amount of daylight entering the light-well, two sets of curtains were installed directly beneath the skylight, one set consisting of four overlapping light-proof curtains to provide for the gross changes, the other of three thin white curtains to give the finer changes often needed in maintaining constancy of illumination. Beneath the diffusion sashes were installed three sets of curtains, one broad light-proof curtain covering the entire ceiling of the room, the edges of which were enclosed to a depth of several inches in a light-tight boxing; and two sets of thin white curtains, one running lengthwise of the room and the other crosswise. These latter curtains could be used for the control and variation of daylight, artificial light or the mixture of the two. In order to vary the amount of artificial light incident on the diffusion sashes, each of the eight units was installed on a separate circuit with voltmeter and rheostat control and provided with a separate switch. By means of all of the controls, any amount of daylight or artificial light or the mixture of the two in any proportion desired could readily be varied from full intensity to extinction, and constancy of illumination could be maintained within a negligible limit of error. The windows also were provided with light-proof curtains. Each of the light-proof curtains, overhead and window, was painted matt white on the inside. When the daylight to be mixed with the artificial light was obtained from the light-well, the curtains over the windows were drawn; and when obtained from the windows, daylight was excluded from the light-well by drawing the curtains under the skylight. By means of these two

1. Donated for use in these experiments by Curtis Lighting, Inc., Chicago.

sets of curtains, window-light or skylight could be mixed with the artificial light as desired.

The tests for the effect on the eye were conducted at four intensities. For the first three of these intensities 100-watt frosted type B Mazda lamps were used. The light from the type B rather than the type C lamp was preferred for these experiments because of its greater difference from daylight in color and composition. However, since the fourth intensity could not be obtained with the type B lamp, bowl-enameled 200-watt type C lamps were used. One intensity was selected for use with all of the foregoing tests: acuity, speed of vision, power to sustain acuity and ocular fatigue. These tests have been described so frequently in former papers [2] that it does not seem necessary to take the space for their description here. In making the tests, the artificial light and the daylight were both taken from the light-well and were mixed in equal proportions. The artificial light, the daylight and the mixture were all made equal in every case at the test surface. In making the equalization of the components of daylight and artificial light for the mixture, the measurements were also made at the test surface.

The results for these tests are given in table 1. The order of ranking as to merit was the same, it will be noted, for the four tests. The artificial light gave the poorest results, the daylight the best results and the mixture of the two in equal proportions an intermediate result. Because of the agreement in ranking for the four tests and the excessive amount of time required to make all four of them, particularly the fatigue test, for all four intensities, the speed test alone was used for the remaining intensities. In all cases, as before, the equalization was made at the test surface. The results for these tests are given in table 2. Again it will be noted for all intensities that the artificial light gave the poorest results, the daylight the best and the mixture in equal proportions an intermediate result. Table 3 gives the results when the daylight used in the mixture was obtained from side windows. For this case the tests were made only for acuity at one intensity and for speed

2. Ferree, C. E., and Rand, G.: The Effect of Variations in Intensity of Illumination on Functions of Importance to the Working Eye, Tr. Illum. Eng. Soc. **15**:769, 1920; The Effect of Variations in Intensity of Illumination on Acuity, Speed of Accommodation and Other Important Eye Functions, Tr. Am. Ophth. Soc. **19**:259, 1921; The Effect of Variation of Visual Angle, Intensity and Composition of Light on Important Ocular Functions, Tr. Illum. Eng. Soc. **17**:69, 1922; The Effect of Increase of Intensity of Illumination on Acuity and the Question of the Intensity of Illumination of Test Charts, Am. J. Ophth. **6**:672, 1923; Further Studies on the Effect of Composition of Light on Important Ocular Functions, Tr. Illum. Eng. Soc. **19**:424, 1924; Intensity of Light and Speed of Vision Studied with Special Reference to Industrial Situations: I, ibid. **22**:79, 1927; II, ibid. **23**:507, 1928; Visibility of Objects as Affected by Color and Composition of Light: I, Personnel J. **9**:475, 1931; II, ibid. **9**:108, 1931.

at the four intensities. The tests were not made for power to sustain acuity and for ocular fatigue for two reasons: (*a*) It was very difficult with our provisions for the control of the window-light to maintain the high degree of constancy that is required in the three minute record used in both these tests. And (*b*) the results for the acuity and speed tests duplicated so closely those obtained when the daylight for the mixture was taken from the light-well that it did not seem necessary to extend the work to include the two more difficult and time-consuming tests. Check observers were used in the verification of the results. Some difference was obtained in the amount of effect for the different observers, but the order of ranking as to merit was in every case the same; that is, the mixture was slightly better than the artificial light alone and slightly poorer than the daylight alone. While the claim to superiority for the mixed light as compared with the artificial light

TABLE 1.—*Comparative Effect of Equal Intensities of Daylight, Artificial Light and a Mixture of the Two in Equal Proportions on Acuity, Speed of Vision, Power to Sustain Acuity and Ocular Fatigue; Light in All Cases from Overhead Sources*

A. Acuity

Intensity (ft.c.)				
Horizontal Component	Vertical Component	Type of Lighting	Acuity	Per Cent Change as Compared with Daylight
2.3	4.2	Daylight	1.352	
2.3	4.6	Mixed light	1.336	1.2
2.3	5.0	Artificial light	1.324	2.1

B. Speed of Vision

Intensity (ft.c.)				
Horizontal Component	Vertical Component	Type of Lighting	Speed of Vision	Per Cent Change as Compared with Daylight
2.3	4.2	Daylight	11.90	
2.3	4.6	Mixed light	11.49	3.5
2.3	5.0	Artificial light	11.17	6.1

C. Power to Sustain Acuity

Intensity (ft.c.)				
Horizontal Component	Vertical Component	Type of Lighting	Ratio Time Clear to Time Blurred	Per Cent Change as Compared with Daylight
2.3	4.2	Daylight	7.57	
2.3	4.6	Mixed light	6.20	18
2.3	5.0	Artificial light	5.00	34

D. Ocular Fatigue

Intensity (ft.c.)				Ratio Time Clear to Time Blurred		
Horizontal Component	Vertical Component	Type of Lighting	Time of Test	Reduced to Common Standard	Per Cent Loss in Efficiency	Per Cent Change as Compared with Daylight
2.3	4.2	Daylight	10 a.m.	3.50		
			1 p.m.	3.42	2.3	
2.3	4.6	Mixed light	10 a.m.	3.50		
			1 p.m.	3.28	6.3	4.1
2.3	5.0	Artificial light	10 a.m.	3.50		
			1 p.m.	3.22	8.0	5.9

is slight in all cases, the results do surely indicate that there is nothing deleterious so far as the more important visual functions are concerned in the mixture of daylight and artificial light from the standpoint of

TABLE 2.—*Comparative Effect of Daylight, Artificial Light and a Mixture of the Two in Equal Proportions on the Speed of Vision at Four Intensities; Light from Overhead Sources*

Intensity (ft.c.)				
Horizontal Component	Vertical Component	Type of Lighting	Speed of Vision	Per Cent Change as Compared with Daylight
6.70	12.06	Daylight	17.70	
6.70	13.30	Mixed light	17.12	3.3
6.70	14.54	Artificial light	16.67	5.8
2.30	4.2	Daylight	11.90	
2.30	4.6	Mixed light	11.49	3.5
2.30	5.0	Artificial light	11.17	6.1
1.15	2.1	Daylight	7.52	
1.15	2.3	Mixed light	7.25	3.6
1.15	2.5	Artificial light	7.06	6.1
0.575	1.05	Daylight	3.79	
0.575	1.15	Mixed light	3.65	3.7
0.575	1.25	Artificial light	3.55	6.3

TABLE 3.—*Comparative Effect of Daylight and Artificial Light from Overhead Sources and a Mixture in Equal Proportions of Artificial Light from an Overhead Source with Daylight from Side Windows, on Acuity and Speed of Vision*

A. Acuity

Intensity (ft.c.)				
Horizontal Component	Vertical Component	Type of Lighting	Acuity	Per Cent Change as Compared with Daylight
2.3	4.2	Daylight	1.352	
2.3	4.6	Mixed light	1.336	1.2
2.3	5.0	Artificial light	1.324	2.1

B. Speed of Vision

Intensity (ft.c.)				
Horizontal Component	Vertical Component	Type of Lighting	Speed of Vision	Per Cent Change as Compared with Daylight
6.70	12.06	Daylight	17.70	
6.70	13.30	Mixed light	17.12	3.3
6.70	14.54	Artificial light	16.67	5.8
2.30	4.2	Daylight	11.90	
2.30	4.6	Mixed light	11.49	3.5
2.30	5.0	Artificial light	11.17	6.1
1.15	2.1	Daylight	7.52	
1.15	2.3	Mixed light	7.25	3.6
1.15	2.5	Artificial light	7.06	6.1
0.575	1.05	Daylight	3.79	
0.575	1.15	Mixed light	3.65	3.7
0.575	1.25	Artificial light	3.55	6.3

color and composition or the difference in the location and type of source used to supply the components for the mixture.

It would appear, therefore, that we must look elsewhere for an explanation of the belief that as good a result is not obtained as might be expected when artificial light is used to supplement daylight at the

close of the working day. When an apparent disagreement of result is obtained between laboratory work and field work, obviously the first thing to do is to look for a disagreement in conditions. In the present case the disagreement in conditions is obvious. In our experiments each test was made with the eye completely adapted to each illumination employed. The experiments were planned with this end in view in order that the effect of color and composition of light and difference in location and type or source might be determined in separation. In field work, the results have been obtained when daylight is mixed with artificial light after hours of exposure of the eye to high daylight intensities. In the following series of experiments we have attempted, therefore, to duplicate as closely as possible the conditions that are found in the practical situation. In these experiments the test for speed alone was used. Two reasons may be assigned for this: (*a*) The conditions were such that it was obviously impossible to use the test for fatigue and power to sustain acuity. And (*b*) the acuity test is less sensitive than the speed test and has not as yet been found to add anything differential in the way of results to those obtained with the speed test.

THE EFFECT OF ADDING ARTIFICIAL LIGHT TO DAYLIGHT IN THE LATE HOURS OF THE AFTERNOON ON SPEED OF VISION

These experiments were conducted in the same room as the work in the preceding section. The observer entered the room in the early afternoon. Tests were taken at intervals of fifteen minutes as the light decreased. When the illumination had reached the intensity chosen, the artificial light was turned on, tests being made immediately before and after the artificial light was added. The tests were then continued at intervals of ten minutes until well after the daylight had disappeared from the room.

The tests were made with the rotary tachistoscope described in former papers. Because of the rapidly changing illumination it was necessary to shorten the time consumed in making the determination of speed. For this reason the time needed to discriminate the opening of the circle was measured for five instead of eight positions as has been the case in all our former work on speed of vision. A correct judgment was required in three of the five positions. Also because of the nature of the series, it was not possible to narrow down the determination of the threshold of speed as carefully and minutely as has been done heretofore. In order too, that as little time as possible should be consumed in making the illumination measurements, the horizontal component alone was read while the series was in progress. The ratio of the vertical to the horizontal component with the type of distribution found in

our optics room was determined in a number of separate series of measurements extending through the afternoon hours. As might be supposed, with an optics room illuminated by a light-well with a diffusion sash swung beneath, this ratio was found to have approximately a constant value for each type of illumination. The horizontal component of illumination at the test surface was measured at the beginning and end of each series of exposures contributing to one determination of speed. An average of these values was taken as the intensity of illumination at which the test was made. The vertical component was computed from the horizontal component by applying the ratio previously determined. On the front surface of the exposure disk in line with the test object and the observer's eye was placed a fixation cross in order that the exposure might begin with the eye as closely as possible in adjustment for the test object. Constancy of position of the eye was secured by having the observer bite a mouthboard in which the impression of his teeth had previously been made and hardened in wax.

A graphic representation of the results is given in the form of curves shown in charts 1 to 3. In these curves speed of vision is plotted on the vertical coordinate and time of day on the horizontal coordinate. Both components of illumination are also shown on the horizontal coordinate. Speed, however, is not plotted against intensity of illumination. This should be kept clearly in mind when inspecting the shape of the curves. While as the afternoon advances the tendency is in general toward a lower illumination, this is not always a smooth progression, as is well known to every one who is familiar with daylight measurements. It frequently happens, for example, that a higher intensity of illumination is found at a later than at an earlier period due to some obscuration of light at the earlier period, particularly in the early and mid-afternoon hours. In fact, several factors contribute to the shape of the curves obtained: rate and direction of change of daylight from test to test during the afternoon in question, rate of adaptation of the eye to the changing light, rate of change in size of pupil, the intensity of daylight at the time the artificial light was added and the proportion between the two components, etc. Because of all of these factors the curves present quite a different appearance from other curves that we have determined for the relation of speed of vision to intensity of light for intensities ranging from 0.5 to 116 foot candles, in which case the eye was allowed thoroughly to adapt to each intensity of illumination, and ample opportunity was had for carefully determining and rechecking the determinations of the speed for each intensity. In case of the present curves, the determinations had to be made as quickly as possible, and the exact conditions obtaining for any curve could not be duplicated for the purpose of repeating and checking the determination. The curves can thus

be considered only as representing the general trend of the function investigated under the conditions imposed. They should by no means be confused with curves intended to show the relation between intensity of light and speed of vision.

In chart 1 the tests were begun at 3:15 p. m. on March 25 and repeated at intervals of fifteen minutes until 6:10 p. m. At this time the daylight had decreased to 1 ft. c. horizontal component, 1.8 ft. c. vertical component, and comfortable reading from ordinary print was barely possible. The speed at this intensity, represented by the reciprocal of the exposure time in seconds needed to discriminate the test

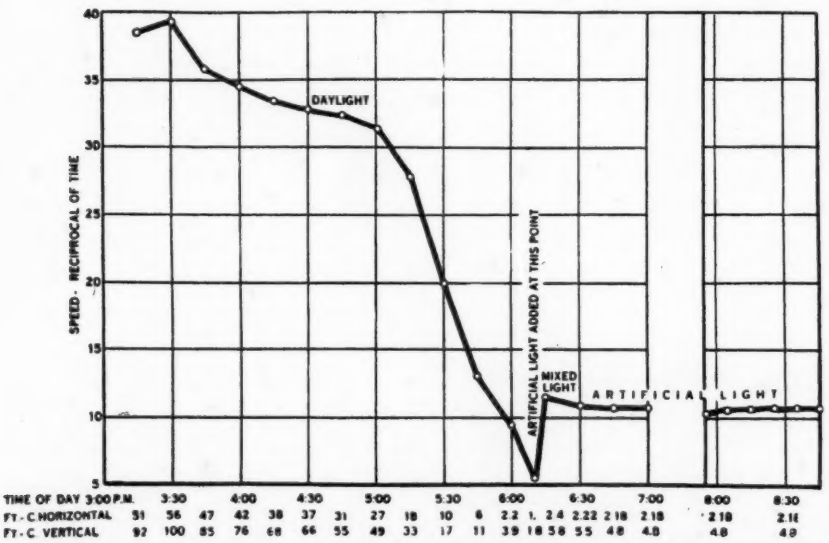

Chart 1.—The effect on speed of vision of adding artificial light to daylight in the late hours of the afternoon. Record taken on March 25.

object, was 5.5. Artificial light was then added, horizontal component 2.18 ft. c., vertical, 4.8 ft. c. The total mixed illumination at the time the test was taken was 2.40 ft. c. horizontal component, 5.2 vertical component. This increased the speed of vision from 5.5 to 11.49, or 109 per cent. The series was then continued until 7:00 p. m., thirty minutes after daylight had completely disappeared and the eye had reached a permanent state of sensitivity to the intensity of artificial light. When the daylight had completely disappeared, the speed had decreased to 10.75, a change of 6.4 per cent. After dinner the tests under the artificial light were resumed from 7:55 until 9:00 p. m. to show the effect of coming from outdoor darkness into a room lighted by 2.18 ft. c., horizontal component, 4.8 ft. c. vertical component, of artificial light. At

the beginning of this period the speed was 10.31; at the close, 10.75, a gain of 4.3 per cent.

In order to show the effect of adding artificial light when the addition was made to higher intensities of daylight, two curves have been selected, one representing determinations made on March 26, the other on May 7. These curves are shown in charts 2 and 3. In the curves shown in chart 2, the tests were begun at 3:30 p. m. and continued at intervals of fifteen minutes until 5:55 p. m., at which time the value of the horizontal component was 2.18 ft. c., the vertical, 3.92 ft. c. Artificial light of the same value of horizontal component, 2.18 ft. c. (vertical component 4.8 ft. c.), was added. The effect was to increase the speed from 10.3 to 14.93,

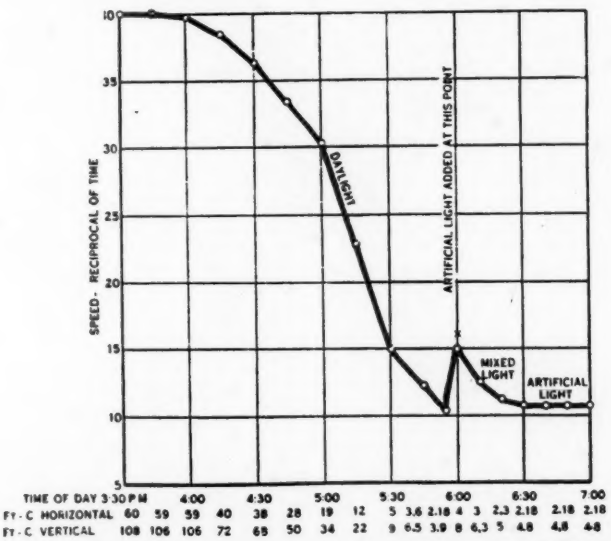
SPEED - RECIPROCAL OF TIME
DAYLIGHT
ARTIFICIAL LIGHT ADDED AT THIS POINT
MIXED LIGHT
ARTIFICIAL LIGHT
TIME OF DAY 3:30 P.M. 4:00 4:30 5:00 5:30 6:00 6:30 7:00
FT.-C HORIZONTAL 60 59 59 40 38 28 19 12 5 3.6 2.18 4 3 2.3 2.18 2.18 2.18
FT.-C VERTICAL 108 106 106 72 68 50 34 22 9 6.5 3.9 8 6.3 5 4.8 4.8 4.8

Chart 2.—The effect on speed of vision of adding artificial light to daylight in the late hours of the afternoon. Record taken on March 26. *X* indicates the speed obtained in a later determination when the eye was fully adapted to the mixed light.

or 45 per cent. As the daylight illumination decreased, the speed decreased to 10.75, a change of 28 per cent.

In the curve shown in chart 3, the tests were begun at 4 p. m. and continued at intervals of fifteen minutes until 6:25 p. m., at which time the intensity of the daylight was 5.6 ft. c. horizontal and 10.1 ft. c. vertical component. Artificial light was then added of an intensity of 6.16 ft. c. horizontal component, 13.6 ft. c. vertical component. The effect was to increase the speed from 12.5 to 25.32, or 102 per cent. As the daylight decreased the speed decreased to 12.99, a change of 49 per cent.

The question has frequently been raised whether it is not better for the eye to exclude the daylight entirely when it has become insufficient

for seeing and to depend on artificial light alone. The results shown in these three curves and of all the other tests we have made are quite definite on this point, so far as the effect on speed of vision is concerned. The speed is greater for the mixture than for the artificial light alone. When the artificial light is added, the increase in speed seems roughly to be all that could be expected from the increase of intensity produced and the state of adaptation of the eye, and as the daylight dies away the decrease appears also to follow roughly the decrease of intensity. Unless some antipathy should be felt to the fluctuation in the eye's adjustments to intensity produced by the abrupt addition of the artificial light and the subsequent dying away of the daylight, we can see no

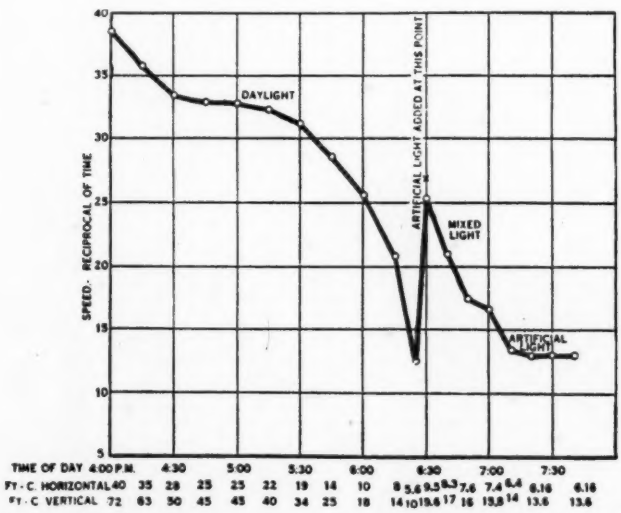
SPEED - RECIPROCAL OF TIME
40
35
30
25
20
15
10
5
DAYLIGHT
ARTIFICIAL LIGHT ADDED AT THIS POINT
MIXED LIGHT
ARTIFICIAL LIGHT
TIME OF DAY 4:00 P.M. 4:30 5:00 5:30 6:00 6:30 7:00 7:30
FY - C. HORIZONTAL 40 35 28 25 25 22 19 14 10 8 5.6 9.5 8.3 7.6 7.4 6.4 6.16 6.16
FY - C. VERTICAL 72 63 50 45 45 40 34 25 18 14 10 13.6 17 16 13.8 14 13.6 13.6

Chart 3.—The effect on speed of vision of adding artificial light to daylight in the late hours of the afternoon. Record taken on May 7. *X* indicates the speed obtained in a later determination when the eye was fully adapted to the mixed light.

serious ocular objection to utilizing the daylight as long as it lasts in the form of a mixture with the artificial light, even when the transition from the one to the other is abrupt. The intensity curve could be made smoother, of course, by substituting the artificial light when the two are at or near the same intensity. If this were done, however, the disagreeable effect of a more abrupt color change would be experienced and the benefit to speed and other working powers of the eye during the period of increased intensity would be lost. Also a valuable and useful amount of daylight would be wasted. Suggestions are offered in the next section which are more satisfactory; one of these at least is also more feasible.

A STUDY OF THE PROBLEM IN RELATION TO THE ADAPTATION OF THE EYE

It has been shown in the previous sections that there is nothing detrimental to the eye in the mixture of artificial light with daylight so far as composition and color are concerned. The effect on the more important visual functions is roughly what would be expected from an illumination ranging in color and composition between daylight and artificial light. Also, no measurable difference in result was found when both components of the mixture were obtained from an overhead source and when one was obtained from an overhead and the other from side sources. A greater total intensity of light is needed, however, during the late afternoon hours to give a satisfactory efficiency to the eye than is required at night or during the day in an inside room. This, we believe, is because of the high intensities to which the eye has been exposed during the day and the rapid rate of decrease of light in the middle and late hours of the afternoon; that is, in its recovery of sensitivity the eye is not able to keep pace with the failing illumination. Until it has had an opportunity to recover its sensitivity, more than the normal amount of light is needed. Thus the deficiency is primarily in the eye itself, owing to the adaptation situation imposed, not in the mixture of the two kinds of light. The amount of the deficiency will in any case obviously depend on the state of adaptation in which the eye is at the time the artificial light is added. In general, it would be supposed that better results would be gotten by turning on the artificial light before the daylight has reached its more rapid stage of rate of decline, because that is when the eye would be expected to experience its greatest lag in adaptation. It should be the purpose of good afternoon lighting to minimize that lag as much as possible. Also, by turning on an artificial light of good intensity when the daylight is still strong, the subjective effects of abrupt changes, both of intensity and of color, are avoided. In other words, the eye should be eased into the artificial illumination gradually and not plunged into it suddenly as happens when the daylight is allowed to grow low before the artificial light is added. The best results, perhaps also the best economy, are obtained by turning on the artificial light before it seems really to be needed and allowing the daylight to fade out of the mixture gradually. When a fairly high intensity of artificial light is used and it is turned on when the daylight is still high, the effect is of a gradual transition from one to the other which is more agreeable to the eye and less detrimental to its efficiency.

Because of our belief that adaptation is the important ocular function involved in afternoon lighting, the investigation was concluded by making a brief study of the more obvious relations of the problem to adaptation. Two sets of experiments were conducted. In the first, a

determination was made of the eye's deficiency in speed at the time the artificial light was added, owing to the adaptation situation imposed. That is, the speed was obtained with the eye fully adapted to a mixture of artificial light and daylight of the same intensity and proportions as were used in the afternoon series when the artificial light was turned on, and the difference was taken between this speed and that obtained in the afternoon series. This was done for the curves represented in charts 2 and 3. The period of adaptation to the mixed light was in each case one hour. In the former case the speed was changed as the result of adaptation from 14.93 to 15.87 (shown at x in chart 2), an increase of 6.3 per cent; in the latter from 25.32 to 27.78 (shown at x in chart 3), an increase of 9.7 per cent.

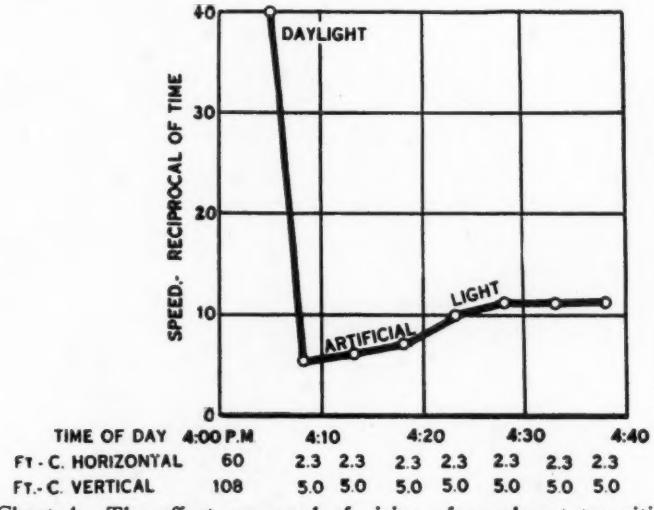
SPEED - RECIPROCAL OF TIME
40
30
20
10
0
DAYLIGHT
ARTIFICIAL LIGHT
TIME OF DAY 4:00 P.M 4:10 4:20 4:30 4:40
FT - C. HORIZONTAL 60 2.3 2.3 2.3 2.3 2.3 2.3 2.3
FT.- C. VERTICAL 108 5.0 5.0 5.0 5.0 5.0 5.0 5.0

Chart 4.—The effect on speed of vision of an abrupt transition from daylight of high intensity to artificial light.

As a supplement to these results, it was determined also what intensity a mixed light of these proportions must have in order to give the speed that had been obtained in the afternoon series if the eye were to be fully adapted to the illumination employed. Again the period of adaptation was one hour. In the first case it was found that when the eye was fully adapted to an illumination of 3.13 ft.c. it attained to the same speed as was given by 4 ft.c. in the afternoon series; in the second case, the same speed at 7.73 ft.c. that it had in the afternoon series at 9.5 ft.c. That is, in the former case the eye required 28 per cent more light to give equally good results because it was not fully adapted, and in the latter case, 23 per cent more light. In other words, according to the results in the first case, roughly speaking, a total of 28 per cent more light would have had to be planned for under the conditions

obtaining in our test room at 5:55 p. m. on March 26 than would have been required to give the same result in an inside room, and 23 per cent more at 6:25 p. m. on May 7.

In the second set of experiments the transition from early afternoon light to artificial light was made abruptly. The intention here was to get some estimate of the total effect of the preexposure of the eye to the higher intensities of daylight on its subsequent powers of performance at the lower levels of intensity used in artificial lighting. In these experiments the eye was exposed for one hour to 60 ft.c. of daylight, horizontal component, 108 ft.c. vertical component, and the speed of vision determined. The daylight was then entirely excluded from the room and the artificial light turned on, 2.3 ft.c. horizontal component, 5 ft. c. vertical component. Speed tests were made immediately and at intervals of five minutes until complete readaptation had occurred. A

TABLE 4.—*Immediate Effect on Speed of Vision of a Sudden Transition to Artificial Light After One Hour of Adaptation to a High Intensity of Daylight, and the Effect at Intervals of Five Minutes Until Complete Readaptation Had Occurred*

Time of Test	Intensity (ft.c.) Horizontal Component	Intensity (ft.c.) Vertical Component	Type of Lighting	Speed of Vision	Illumination Required to Give This Speed with Eye Fully Adapted	Effective Value of Artificial Light in per Cent
4:05 p.m.	60.0	108	Daylight	40.00	60.00	
4:08	2.3	5	Artificial light	5.46	0.83	36
4:13	2.3	5	Artificial light	6.17	0.94	41
4:18	2.3	5	Artificial light	7.19	1.40	61
4:23	2.3	5	Artificial light	10.10	1.87	81
4:28	2.3	5	Artificial light	11.17	2.30	100

graphic representation of the results is given in chart 4. The difference in the speed at the beginning and end of the period under artificial light shows the full effect of the daylight preexposure. At the beginning of this period it was 5.46; at the close, 11.17, an increase of 105 per cent.

As a supplement to these results, determinations were made of what intensity of light was needed with the eye fully adapted to the artificial light to give each of the speeds obtained while the eye was progressively adapting. The results of these determinations are given in table 4. It will be seen that when the eye was fully adapted to the artificial light, only 0.83 ft. c. (36 per cent) was required to give a result equal to that obtained from 2.3 ft. c. immediately after the change was made from daylight to artificial light; at the end of five minutes only 0.94 ft. c. (41 per cent) was required; at the end of ten minutes, 1.4 ft. c. (61 per cent); at the end of fifteen minutes, 1.87 ft. c. (81 per cent), and at the end of twenty minutes, 2.3 ft. c. (100 per cent).

By the use of artificial daylight with proper attention to adaptation effects, the transition from day to night lighting can, of course, be made

still less conspicuous. In one of our laboratory rooms provided with a combined daylight and artificial daylight skylight, for example, the change can be made unnoticeable. While a skylight is not feasible for general use, much can be accomplished with desk and reading lamps equipped to give artificial daylight. Aside from the foregoing adaptation factor, the change from daylight to Mazda light is annoying from the standpoint of color and the visual quality of the light. 1. Uncorrected Mazda light has a great deal of color. Illuminated with it, the paper has an orange-yellow appearance. Black letters or other characters do not stand out from the background as clearly as on a white surface. The sensation difference between black and color is less than between black and white. 2. Mazda light is "fuzzy," while artificial daylight is smoother in quality. There is probably better focusing for artificial daylight and less scatter of light by the media of the eye. The clearer vision, which is obtained with light properly corrected for color and composition, is very helpful to old eyes and to eyes having residual refractive errors or defective vision from any cause whatsoever. 3. Mazda light is very irritating to many supersensitive and pathologic eyes. To a great number of them night work is made possible and even comfortable by the use of artificial daylight. The next great step in the history of lighting is to put artificial daylight on a production basis. Adequate intensities have been made easily possible, diffusion and distribution of light have been fairly well taken care of and means have been devised for eliminating glare from the source with any intensity of light that is apt to be used.[3] Color and composition of light are without question the outstanding cardinal problem in commercial and industrial lighting.

CONCLUSIONS

The outcome of the foregoing experiments is largely negative. As has already been indicated, uncertainty has been felt both in the formulation of the problem and in the evaluation of the results obtained because of the varied and unsettled nature of the opinions that have been held with regard to the visual effects that are produced by mixing artificial light with daylight. A few conclusions, however, are suggested:

1. So far as the more important visual functions are concerned, there is nothing especially deleterious in the mixture of daylight and artificial light from the standpoint of color and composition or in the difference in type of source ordinarily used to supply the components of the mixture. When the light was mixed in equal proportions—both components from the light-well or one from the light-well and the other

3. In this connection it may be noted that we have recently devised lighting units of different types which are glareless for lamps ranging from 25 to 1,000 watts. These units at least indicate the possibilities that are ahead.

from side windows—and the tests were made at equal photometric intensities at the test surface, the artificial light gave the poorest result, the daylight the best result and the mixture of the two an intermediate result. The effect was roughly what would be expected from an illumination ranging in color and composition between daylight and artificial light.

2. A greater total intensity of light is needed, however, during the late afternoon hours to give a satisfactory efficiency to the eye than is required at night or during the day in an inside room. This is because of the high intensity to which the eye has been exposed during the day and the rapid decrease of light in the middle and late hours of the afternoon; that is, in its recovery of sensitivity the eye is not able to keep pace with the failing illumination. The deficiency is primarily in the eye, owing to the state of adaptation imposed, and not in the mixture of the two lights.

3. The loss in visual efficiency due to this lag in adaptation can be decreased and many of the unpleasant subjective effects due to the abrupt transition from daylight to artificial light can be minimized by providing for a good intensity of artificial light and adding it while the daylight is still high. When the daylight is allowed to become low before the artificial light is turned on, the maximum lag in adaptation is experienced and the full effects of a sudden and disagreeable change of both intensity and color of light are produced. When a fairly high intensity of artificial light is used and it is turned on while the daylight is still high, the effect is of a gradual transition from one to the other, which is more agreeable to the eye and less detrimental to its efficiency. One of the purposes of good afternoon lighting should be to make the transition from daylight to artificial light as gradual as possible.

4. By the use of light properly corrected for color and composition, the transition can, of course, be made still less conspicuous. In one of our laboratory rooms provided with a combined daylight and artificial daylight skylight the change from day to night lighting can be made unnoticeable. While a skylight is not feasible for general use, much can be accomplished with desk and reading lamps equipped to give artificial daylight.

SIZE AND SHAPE OF OCULAR IMAGES

I. METHODS OF DETERMINATION AND PHYSIOLOGIC SIGNIFICANCE *

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RELATIVE DIFFERENCES IN THE SIZE AND SHAPE OF OCULAR IMAGES

Leaving aside pathologic conditions, one usually considers but two factors in determining whether the eyes of a person are functioning properly: first, the refraction and, second, the muscle balance. If there are emmetropia and orthophoria for both distance and near, it is assumed that there is nothing the matter with the eyes as far as their functioning is concerned. There is a third factor, however, which appears to be of importance. This is the relative size and shape of the ocular images of the two eyes. The importance of this factor becomes evident when one considers the use of the eyes in binocular vision and the physiologic part played by the brain when the ocular images of the two eyes are combined.

For the purpose of elucidation, figure 1, which represents a mechanical model of the physiologic processes of binocular vision, is helpful. The eyes acting together are similar to a stereoscopic camera with a special device for superimposing the two optical images formed at the focal planes of each half of the camera. The lenses (L and L') would correspond to the dioptric systems of the eyes and the plates (P and P') to the two retinas. The optical system, containing mirrors and lenses M and M', L_1 and L_2 would correspond to the optic tract. The plate B on which the images from each half of the camera are superimposed, would correspond to those portions of the brain in which the images are fused. In order that the two images at B shall be superposed, i. e., coincide as nearly as possible, three conditions are necessary: First,

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* From the Department of Research in Physiological Optics, Dartmouth Medical School.

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the two cameras must be pointed toward the same object field; i. e., the eyes must be looking in the same direction. Second, the images formed at the plates P and P' must be in sharp focus; that is, the cameras must be focused, or the refraction of both eyes must be correct. Third, the images formed at the two plates P and P' must be the same size and shape. If these conditions are not fulfilled, the superposition at B will be imperfect.[1] For instance, suppose lens L, although forming a sharp image, is of a shorter focal length than L'; then the image formed at P would be smaller overall than that formed at P', and the two would not superpose. Such an ocular condition exists in cases of aphakia and high degrees of anisometropia when the refraction is fully corrected.

In the stereoscopic camera, the size of the images formed at the focal planes or plates is governed by one factor only, namely, the distance of the second nodal point of the lens from the plate. The shorter this distance is, the smaller the picture. This is equally true of the optical image formed by the dioptric system of the eye. If the nodal point of the dioptric system of one eye is nearer the retina than that of the other, the dioptric image formed in that eye will be smaller and vice versa. But this applies only to the dioptric image as distinguished from the ocular image, i. e., the image that is carried to the brain. The size and shape of the latter is dependent not only on the size of the dioptric images formed, but also on the particular distribution of the retinal elements, the rods and cones. This is due to the fact that, in general, each receptor has a primary connection with a particular center in the brain which also acts for a particular receptor in the other eye. Any two receptors that are connected with the same center in the brain are said to be corresponding retinal points. Tschermak [2] expressed it as follows:

> The daily experience of single vision with both eyes, or of haploscopy (Oppel), already teaches us that there is a functional association of the two eyes. On closer investigation, this functional association shows that it concerns the individual units of the monocular space perception, which, generally speaking, may be called "retinal points." These, on the one hand, are the foveal cones, and on the other, the groups of rods and cones corresponding to the extrafoveal circles of sensation. . . . These physiologic units show a correspondence in the functional space value or local signs in pairs, hence, are "coincident points" (Hering); there is a "*correspondence*" (Fechner) or elementary congruence of visual direction (Tschermak) of both retinas. Hitherto, this was called "identity" (J. Müller). How-

1. The parallax that would exist in these images, due to the separation of the lenses in the camera with an object anywhere but at infinity, is ignored as being immaterial to the general concept presented here.

2. Tschermak, A.: Optischer Raumsinn, in Bethe; von Bergmann, Embden and Ellinger: Handbuch der normalen und pathologischen Physiologie, Berlin, Julius Springer, 1930, vol. 12, p. 891.

ever, in view of the actual noncorrespondence of the retinal points, of similar visual direction in other functional components (especially impression value and depth value. . . .) this does not seem to be suitable. Let us assume from the start that in a person who has normal binocular vision, this turns out to be a fixed and innate correspondence, so that we may define it as an *elementary,* fixed congruence of *visual direction based on inheritance or the laws of development.*

As a result of this arrangement, even if dioptric images of exactly the same size were formed on both retinas the ocular images at the brain

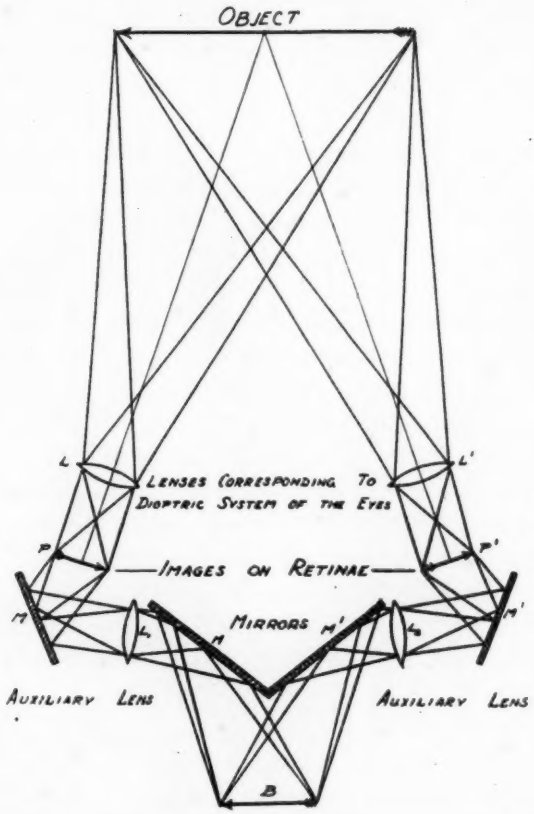

Fig. 1.—Schematic model of the physiologic processes of binocular vision.

would appear to be the same size and shape only if the distribution of nerve elements in both eyes were exactly the same. For example, if the separation of the elements in the right eye were greater than that in the left, the ocular image at the brain received from the right eye would appear smaller than that received from the left and vice versa.[3] Thus

3. This relationship is evident from the schematic diagrams in figure 2. In the upper figure the distribution of the retinal elements is assumed to be identical in both eyes; i. e., oa = o'a' and ob = o'b'. A represents the brain center with which the corresponding retinal elements a and a' are connected and B that with

the existence of a difference in the size of ocular images between the two eyes may be due either to a difference in the size of the dioptric images formed on the retinas (an optical phenomenon) or to a difference in the distribution of the retinal elements (an anatomic phenomenon), or both.

With this general view of the factors that determine the relative size and shape of the ocular images, the various types of differences that

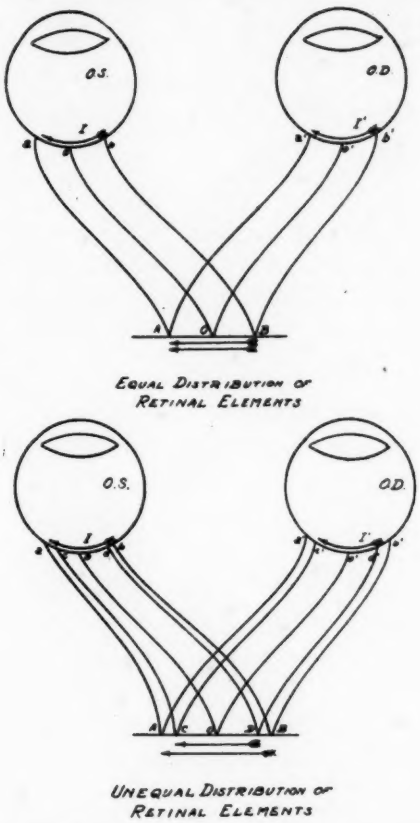

Fig. 2.—Effect of distribution of retinal elements on relative size of ocular images.

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which b and b′ are connected. If the dioptric images I and I′ are the same size on the retinas, they will appear of the same size at the brain. In the lower figure the distributions of the elements are assumed to be such that those in the right eye are more separated than those in the left. Then equal dioptric images on the two retinas will appear of different size at the brain. The image in the right eye will appear smaller than that in the left, for the end-points of the dioptric image of the right eye will fall on retinal elements c′ and d′, which are connected with brain points C and D, and the points C and D are nearer together than the brain points A and B, with which the end-points of the image in the left eye are connected.

may be found will be considered. In the order of their simplicity, they might be listed as follows:

1. Symmetrical differences, or differences in size
   (*a*) Overall
   (*b*) Meridional
2. Asymmetric differences, or differences in shape
   (*a*) Progressive increase or decrease in size across the visual field
   (*b*) Barrel and pincushion distortion
   (*c*) Warped or irregular distortion
3. Combinations of 1 and 2.

Examples of symmetrical size differences are as follows:

1. The ocular image of one eye may be symmetrically larger or smaller overall than that of the other (fig. 3 *A*).

2. The ocular image of one eye may be symmetrically larger or smaller in one meridian than that of the other (fig. 3 *B*).

3. The ocular image of one eye may be symmetrically larger in one meridian and smaller in the other meridian than that of the other eye (fig. 3 *C*).

4. There may be various combinations of 1, 2 and 3.

The foregoing are the simplest and most easily determinable types of differences between these ocular images. The effect of corrections for these types will be described in a later paper by Carleton and Madigan.[4]

Beyond these simple types, which might properly be called size differences, there are other types of differences designated as asymmetric, which are differences in shape. For example, the ocular image in one eye may be progressively larger in the right field and progressively smaller in the left field than that of the other eye. (This is shown in figure 3 *D*). Such an effect is produced by an ordinary flat prism.[5] This type of distortion will be dwelt on later. As another example of asymmetric size difference, one ocular image may be distorted, relative to the other, by way of an enlargement or diminution that progressively increases in all directions from the axis of vision (fig. 3 *E* and *F*), a barrel or pincushion distortion effect.

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4. Carleton, Elmer H., and Madigan, Leo F.: Size and Shape of Ocular Images: II. Clinical Significance, Arch. Ophth., to be published.

5. A detailed description of how prisms produce this effect will be given later. See also Ames, A., Jr.; Ogle, K. N., and Gliddon, G. H.: Corresponding Retinal Points, the Horopter and Size and Shape of Ocular Images, to be published. A set of distortionless prisms has been designed, and the American Optical Company has made them for us.

In considering the variation in size or shape of one ocular image it has been assumed, up to the present, that in normal eyes the ocular images were symmetrically disposed about the axis of vision. Such, however, is not the case. It has been recognized that usually the ocular images are asymmetrically distorted in the horizontal meridian, relative to the axis of vision. This condition shows itself in the Hering-Hillebrand horopter deviation. Usually the ocular images progressively

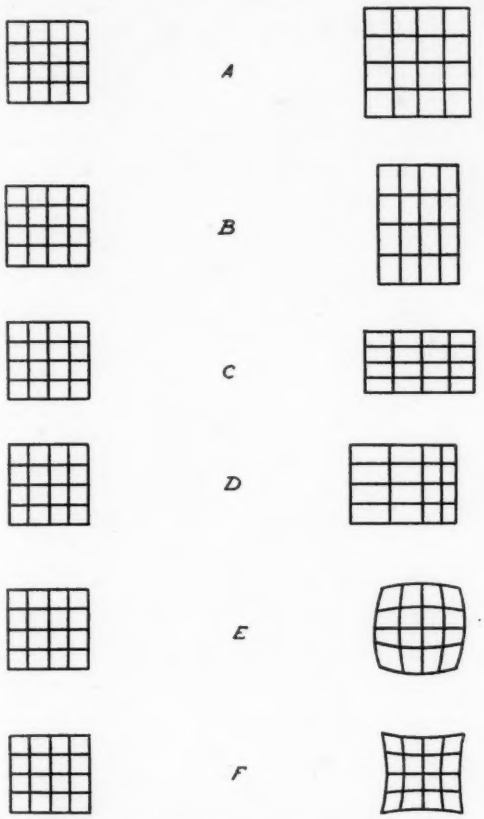

Fig. 3.—Superposed ocular images in the brain.

increase in size across the visual field, being smaller on the nasal sides and larger on the temporal sides (fig. 3*D*). This distortion will be discussed later. The interesting point that this brings out is that for a theoretically normal condition not only must the ocular image in each eye be the same size, but also the total amount of asymmetry of both eyes must be equated to a normal standard.

Besides the types of size and shape of ocular images mentioned, there are a number of other retinal incongruences, a consideration of which is beyond the scope of this paper.

METHODS OF DETERMINING DIFFERENCES IN THE SIZE AND SHAPE OF OCULAR IMAGES

With the foregoing description of the general nature and various types of differences in the size and shape of ocular images in mind, the methods and apparatus for determining these differences will be considered.

The simplest way to describe relative differences in the ocular images is in terms of per cent, i. e., to designate one image as so many per cent larger or smaller than the other. Assume that for a given person the dioptric image in the right eye is 2 per cent larger overall than that in the left eye. As he looks with both eyes at the center of a square, e. g., that shown in figure 4, this difference may not be apparent. For, although the two ocular images are of different size and fall on noncorresponding retinal points, they may fall within corresponding *fusional areas* (Panum's areas) and so may be fused and appear as one. That is, the ability to fuse similar images that lie within these areas tends to mask a difference in size. Presumably, therefore, the

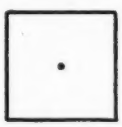

Fig. 4.—Appearance of object when viewed binocularly with difference in size of ocular images.

difference could be perceived if fusion could be prevented. Since fusion occurs only for similar images, it can be prevented by presenting to each eye dissimilar objects of the same size. This is accomplished with the clinical instrument that will be briefly described.

If the person is placed before the mirrors M and M' (fig. 5),[6] he will see with the right eye a target (T'), as shown at A on the right side of figure 6. At the center of this target is a circle, and at an angular distance of 4 degrees from the center is a series of point sources of light produced by illuminating small holes from behind. With the left eye he will see a target (T) (fig. 5) as shown at B at the left of figure 6, on which there is a circle at the center, identical with that on the other target and a series of dash lines located so that the centers of the gaps are exactly the same distance from the center circle as are the star points of light in the right-hand target. On looking at these two targets at the same time the center circles will fuse, but the star points of light and the dash lines will not. With the difference of 2 per cent in the size

6. Ames, A., Jr., and Gliddon, G. H.: Ocular Measurements, Tr. Sect. Ophth., A. M. A., 1928, p. 102.

of the ocular images it will be observed, when the center circles are fixated, that the star points lie slightly outside of the dash lines. In view of the fact that when one fixates the circles the light points and dash lines are seen on the peripheral retina, this judgment is a difficult one to make, especially for untrained observers. This difficulty is avoided if, instead of looking at the circles one looks directly at the point sources of light and the corresponding dash lines. Then the circles will be imaged on the peripheral retina and, being similar, will fuse.[7] Any difference in the size of the ocular images becomes

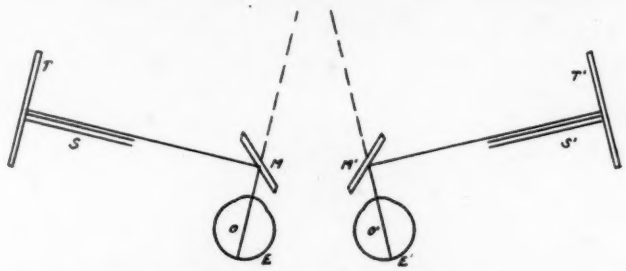

Fig. 5.—Diagrammatic plan of the clinical instrument.

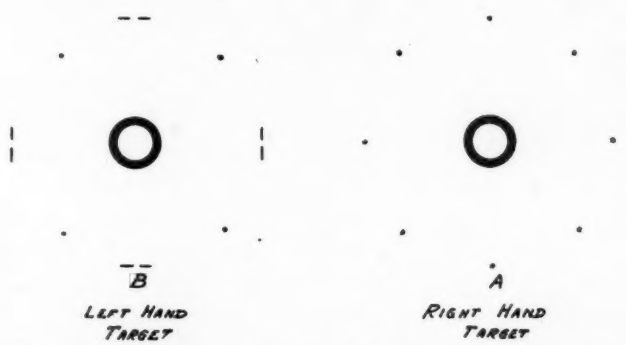

Fig. 6.—Types of visual targets for right and left eye used with clinical instrument.

apparent so far as the star points fail to lie at the centers of the gaps in the dash lines. For example, if, when looking at the right light and line *a* in figure 7, the point source appears to an orthophoric observer to be farther from the circle than the line, the ocular image on the temporal retina of the right eye is larger than that on the nasal retina of the left eye. And if, on looking left at the light and line *b*, above

7. It is important that the outer boundaries of the two targets be dissimilar so that there will be no tendency to fuse anything but the circles at the center of the targets. This is accomplished by putting a screen with a hexagonal opening over one target.

at *c* and below at *d*, the star points are all outside the lines, we know that the ocular image of the right eye is larger overall than that of the left eye.[8]

The magnitude of the difference in size of the ocular images is determined by employing a series of zero power lenses that magnify the size of the image.[9] Two sets are used: One changes the size overall, while the other changes the size in one meridian only. These lenses have no power; that is, they have no effect on the vergence of the light. The weakest lens changes the size by 0.25 per cent, and the strongest by 5 per cent; they vary in steps of 0.25 per cent. In the determination of size difference, if the image of the right eye appears larger overall, a lens that will equalize the two images is put before the left eye. When

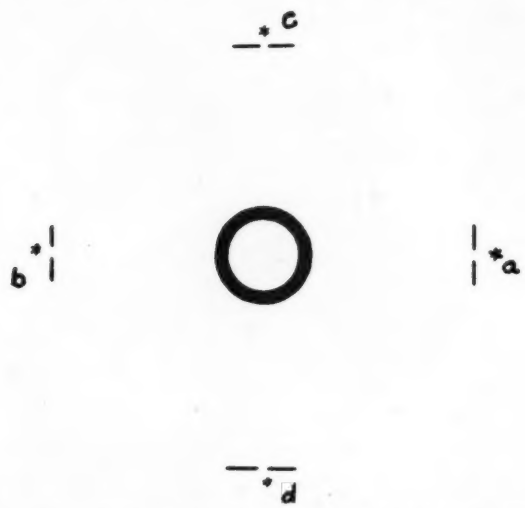

Fig. 7.—Appearance of targets when the ocular image in the right eye is larger than that in the left.

the size of the ocular images differs in one meridian only, the lenses that change the size in one meridian only are used.

The first set of these lenses, which was the result of a considerable amount of study, was made for the department by the American Optical Company in 1929. Although these sets have worked very well, they were subject to some modifications. New sets were designed, which have just been delivered. The American Optical Company has also made the corrective lenses given the patients. The making of both the

8. This method of determining differences in size is the same as was described in our previous paper (Ames and Gliddon [footnote 6]).

9. These lenses will be described in detail later (Ames, A. Jr.; Gliddon, G. H., and Ogle, K. N.: Lenses for Changing the Sizes and Shapes of Dioptric Images, to be published.

trial sets and the corrective lenses has been a difficult manufacturing problem necessitating somewhat new methods.

Some idea of the precision of this method of determining the size differences can be obtained from the following evidence which indicates that for those whose fusion faculty is good and whose phoria is not too large it is quite accurate:

First, practically all of the patients report that a noticeable displacement of the star points of light relative to the lines is produced by a change of size of the image of one eye by 0.50 per cent. Many can detect a difference of 0.25 per cent and some less than 0.25 per cent.

Second, determinations of the size differences of patients whose size is corrected, taken after a lapse of time, usually check within 0.25 per cent.

Third, the measurements obtained by this method agree closely with those made by apparent frontal plane horopter and grid-nonius horopter methods, which will be described later.

The method of measuring size described, however, is subject to the following criticisms: First, it necessitates eye movements to the right and left, which may introduce undetermined factors. Second, it gives measurements for one angular distance only, i. e., 4 degrees from the center of fixation.[10] Third, as already indicated, the method is unsatisfactory for persons whose phoria is large. Many observers with large horizontal phorias can hold their fusion only when similar figures are seen centrally, fusion being impossible for similar objects seen peripherally. Size measurements become practically impossible in such cases.

In an effort to meet these objections, another type of apparatus was developed, based on Hering's horopter apparatus and on a modification of Tschernak's binocular-nonius device. This method at present gives measurements in the horizontal meridian only and, as used clinically, only at the fixation distance of 2.5 diopters.[11] The apparatus for making measurements by this new method is used in conjunction with the clinical machine (fig. 8).

In principle this method is the same as the one just described, in that there are similar objects in the field of view which fuse and dissimilar ones at determinable lateral distances which do not fuse. It differs, however, in that the similar objects are at the point of fixation while the dissimilar ones are imaged on the peripheral retina, and in that the position of the dissimilar objects can be varied laterally to each other. Figure 9 is a diagrammatic plan of the apparatus. Vertical wires at *a*, *a*, *a* can be moved along lanes that converge on the cyclopian nodal point.

10. Targets having extra sets of lights and lines were found to be too confusing to the patients for satisfactory clinical use.

11. In principle it can be applied in other meridians and at all distances.

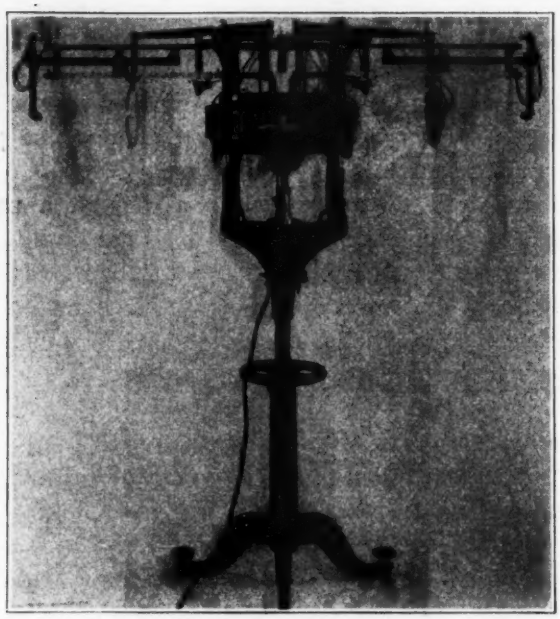

Fig. 8.—Front view of new ocular measuring instrument.

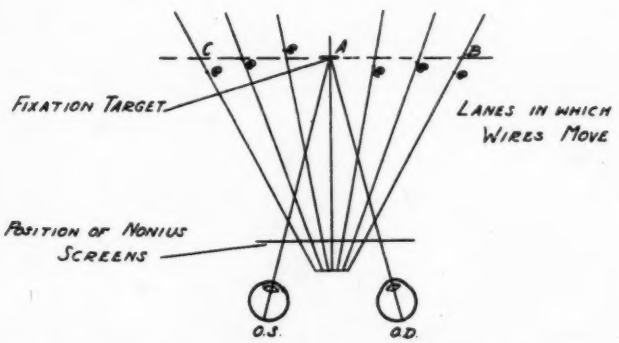

Fig. 9.—Diagrammatic plan of the horopter apparatus.

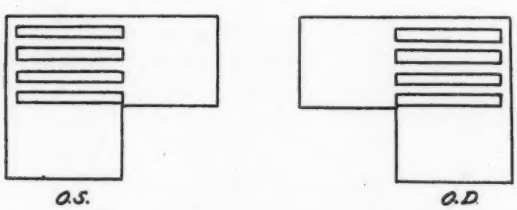

Fig. 10.—Screens used in grid-nonius device.

Screens (fig. 10) are so placed before the eyes that, while allowing the fixation target at *A* (figs. 9, 10 and 11) to be seen by both eyes, they affect the appearance of the lateral wires at *C* and *B* as follows: The right eye can see only the upper halves of the lateral wires at *B* (fig. 9), which the grid *D* causes to appear as dash lines (fig. 11 *b*), and the lower halves of the lateral wires at *C*, which appear as solid lines (fig. 11 *c'*). The left eye sees only the lower halves of the lateral wires at *B*, which appear as solid lines (fig. 11 *c*), and the upper halves of those at *C*, which appear as dash lines (fig. 11 *b'*). The observer fixates on a square at *A* (fig. 11). By means of convenient handles he moves the wires forward and back, causing the dash and solid lines to appear to move laterally relative to each other (fig. 12 *b*, *c* and *b' c'*). While

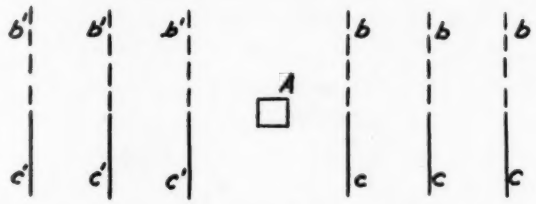

Fig. 11.—Appearance of wires when adjusted on the horopter, using the grid-nonius method.

Fig. 12.—Appearance of wires when not on the horopter, using the grid-nonius method.

maintaining his fixation at *A*, he adjusts them until they are collinear, i. e., until the dash line is a continuation of the solid line. The position of a wire when so adjusted gives a measure of the difference in the angular distance of corresponding retinal points of the two eyes from the points of fixation for that particular peripheral angle. By an adjustment of the whole series, measurements are obtained for a number of different peripheral angles. From these data the relative size and shape of the ocular images in the horizontal meridian can be determined. The term "grid nonius horopter" is used to describe this method.[12]

12. This is a development of Tschermak's binocular-nonius method (Fischer, F. P.: Fortgesetzte Studien über Binokularsehen, Arch. f. d. ges. Physiol. **204**: 234, 1924).

The advantages of this method are as follows: It avoids eye movements. The fusion of the eyes can be maintained by persons with large phorias. It gives measurements at a number of points in the visual field. It gives not only more complete information as to the relative sizes of the ocular images, but also information concerning asymmetric distortions in the horizontal meridian. It also gives a definite determination of what has been termed "retinal slip," a phenomenon correlated with phoria. The method is subject to the objection that it necessitates judgments in indirect vision. These judgments are much facilitated, however, by the particular forms of the dissimilar objects and also by the fact that they can be moved rapidly by each other. The threshold discrimination of such settings is about twice as large [13] as that by the other method, so that more settings are necessary to obtain the same accuracy of size determinations.

It is regretted that there is not space to describe in more detail the nature of the findings that have been made with this apparatus. Those who are interested will find this information in our paper entitled "The Horopter and Corresponding Retinal Points." [14]

PHYSIOLOGIC EFFECT AND NATURE OF THE SIZE AND SHAPE OF OCULAR IMAGES

Having described the general nature of differences in the size and shape of ocular images and how these differences can be measured, their physiologic and psychologic significance will be briefly considered. The complicated and technical nature of the factors involved prevent, at this time, a detailed presentation of what is known on this subject. As a matter of fact, very little is known, since the field is a new one. However, certain determinations have been made, the significance of which seems to be of sufficient importance to warrant their being pointed out at this time.

Effect of the Size and Shape of Ocular Images on Vision.—What rôles do the size and shape of the ocular images play in the act of seeing? The curvature of the crystalline lens controls the sharpness of the dioptric image formed on the retina. Through the vergence faculty the pointing of both eyes at the same object is controlled. The size and shape of the ocular images also play important parts in vision. It is on them that the apparent position of objects in space as determined

13. Ames, A., Jr., and Ogle, K. N.: Size and Shape of Ocular Images: III. Visual Sensitivity to Differences in the Relative Sizes of the Ocular Images of the Two Eyes, Arch. Ophth., to be published.

14. Ames, A., Jr.; Ogle, K. N., and Gliddon, G. H.: Corresponding Retinal Points, the Horopter and Size and Shape of Ocular Images, to be published.

by binocular vision depends.[15] An adequate exposition of this matter involves the horopter and corresponding retinal points. In general, the reason for this is that depth perception arises from the disparity of the images in each eye relative to corresponding retinal points. Any variations in the size and shape of the ocular images produce a difference in this disparity, and so change the apparent position of objects in space.

As a result, any abnormal difference between the size or shape of the ocular images in a horizontal direction deranges the apparent position of objects in the visual field. The simplest form of this derangement is an apparent horizontal rotation of the visual field around a vertical axis at the point of fixation. This can be produced by an overall size change in the ocular image of one eye. The accompanying table gives the calculated amount of such rotation in degrees, produced at different distances, if the ocular image of one eye is larger than that

Angular Rotation of Field in Degrees with Fixation Distances Indicated

Difference in Size of Dioptric Images of the Two Eyes, per Cent	Computed Values for 65 Mm. P. D., Degrees			Experimental Checks					
				K. N. Ogle 63 Mm. P. D., Degrees			F. D. Comfort 63 Mm. P. D., Degrees		
	40 Cm.	76.5 Cm.	6 M.	40 Cm.	76.5 Cm.	6 M.	40 Cm.	76.5 Cm.	6 M.
0.5	1.8	3.3	25.1	.....	.....	....	.....	.....	22.4
1.0	3.5	6.6	43.1	4.2±1.2	7.2±0.9	40.0	2.7±1.0	5.8±1.4	....
2.0	7.0	13.0	61.7	7.2	.....	....	5.5	.....	....
3.0	10.4	19.0	70.2	9.5±1.7	15.6±2.3	....	10.2±1.1	16.3±1.4	....

of the other in the horizontal meridian by the percentages indicated. The table also gives the amounts of rotation as determined experimentally.

This rotation of the visual field can be very simply demonstrated by the following experiment. A long piece of white cardboard is so mounted that it can rotate about a vertical axis (fig. 13 *a*). Vertical lines are drawn on each side of a mark at the center. Attached to the cardboard is an indicator (*b*) that gives its position of rotation in degrees (*c*). To eliminate monocular depth judgments, the card must be viewed through a slit in a screen and the eyes must be closed during actual movement of the card. The test consists in attempting to adjust the card in a position that is apparently normal to the median plane while looking at the mark at the center. An observer without size difference in the horizontal meridian will set it nearly in a normal position. If a size lens is put before one of his eyes and he again tries to set the card

15. Ames, Ogle and Gliddon (footnote 14). The best general presentations of the subject are those of Tschermak and Hofmann which contain very complete bibliographies (Tschermak [footnote 2]. Hofmann, F. B.: Die Lehre vom Raumsinn, in Graefe-Saemisch: Handbuch der gesamten Augenheilkunde, ed. 2, Leipzig, W. Engelmann, 1920-1925, vol. 3, chap. 13).

in a position apparently normal to his direction of regard, he will find it necessary actually to rotate the card approximately to the extent shown in the table. It should be noted that the amount of this rotation is of a large order and also that the same amount of relative difference in the size of the ocular images produces different amounts of apparent rotation at different distances from the observer. This indicates that difference in size causes not only a false binocular depth interpretation but one that varies with different distances of fixation.

If the relative shapes of the ocular images are distorted, as happens when flat prisms are placed before the eyes, base in or base out, the visual field instead of being rotated will appear more concave or convex.[5] This follows from the fact that the ocular image of one eye relative to that of the other is made larger on one half of the field and smaller on

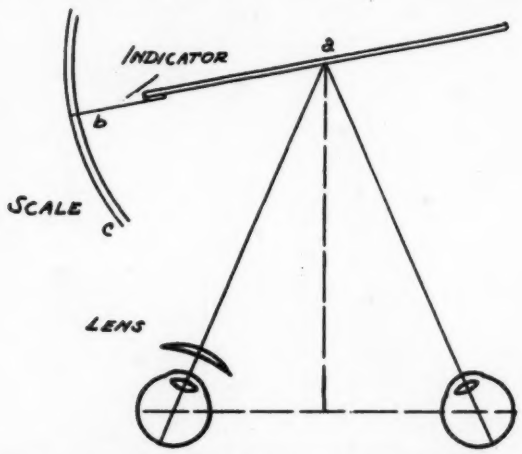

Fig. 13.—Method of demonstrating rotation of the visual field with a change of size of ocular image in one eye.

the other half. The amount of percentile change in size relative to the degrees of rotation is the same as that given in the table.

Locus of Manifestation of Size Differences.—The perception of depth is a phenomenon that takes place in the brain, from which it follows that differences in the size and shape of ocular images manifest themselves, not in the eyes themselves, but in the brain, where the images from both eyes are combined. The locus of the beginning of an excitation is ordinarily at the exterior terminus of a receptor nerve. A prick from a needle affects a receptor nerve ending, and the innervation is carried to the brain. So in monocular vision, the beginning of an excitation is at the cones and rods of the retina. For example, a blurred image affects the cones and rods in a particular manner; the resultant stimulation is carried to the brain by the optic nerves. On the other hand, the locus of the beginning of excitation arising from

differences in the two ocular images is not in the eyes themselves, but in the brain, where the images from each eye are combined. That is, consciousness of the similarities or dissimilarities of the two images arises only in a comparison of one image with the other. Reference to figure 1 may be helpful. As the diagrammatic stereoscopic camera represents, it is only at the plate marked *B*, where the pictures from each half of the camera are superposed, that relative differences can become apparent. This fact must be appreciated for a clear understanding of the problem. It also may account for the neurologic characteristics of the symptoms associated with a difference in the size of ocular images, which will be described in a later paper by Carleton and Madigan.[4]

Threshold Sensibility to a Difference in the Size and Shape of the Ocular Image.—The amount of the smallest difference that can be perceived between two ocular images superimposed in the brain is most important. It is the threshold value for size differences. It gives the accuracy with which size differences can be determined and also an indication of the size differences that can be tolerated. Investigations by others as well as those made at this laboratory [13] show that differences in the size of the ocular images of about 0.25 per cent may be distinguished. On the basis of threshold values, a difference in the size of the ocular image of, say, from 0.50 to 1.00 per cent should have about the same physiologic significance as an abnormal refractive condition of from $\pm$ 0.25 to $\pm$ 0.50 diopters. More detailed information on this matter and the effect of fusional areas on difference in size can be found in a paper to be published later.[13]

Size Amplitude.—In view of the important rôle that the relative size of ocular images plays in vision and the nicety with which they must correspond, it would seem natural to expect that some physiologic processes exist that affect the shape and size of the ocular images. There are two possible ways in which a change in the size and shape of the ocular image could be produced: one by a change in the dioptric image, and the other by a change in the anatomic positioning of the retinal elements.

There is the following evidence that changes do take place in the size and shape of the ocular images:

First, there is a change in the overall size of both ocular images with accommodation. With the increased curvature of the crystalline lens the nodal points of the dioptric system move forward, causing a calculated increase in the size of the dioptric images formed at the retina. The calculated increase resulting from this cause is about 1 per cent for 2.5 diopters of accommodation.

Second, there is a change in the asymmetric distribution of corresponding retinal points from distant to near vision,[16] the Hering-Hillebrand horopter deviation increasing with near vision. The magnitude of this asymmetric change of the ocular images at 8 degrees is about 2 or 3 per cent.

Third, there is the disparity of corresponding points with abnormal pointing of the eyes found with phoria,[6] which will be described later. There is not as yet sufficient evidence to show whether this is of the nature of a slip that takes place over the entire retina of both eyes or a distortion in the shape of the foveal regions of the ocular images relative to other parts.

Fourth, there is definite evidence that a differential change of the ocular images in the vertical meridian occurs when one looks left or right of the median plane. For example, on looking to the right 8 degrees from the median plane, the ocular image in the right eye appears to decrease about 2 per cent in the vertical meridian. Accompanying this change in the vertical size there is a change in the apparent distributions of the retinal elements in the horizontal meridian of the two eyes. This change is manifested by a decrease in the Hering-Hillebrand horopter deviation as one looks to the right or left of the median plane.[14]

Whether the aforementioned changes in the ocular images are due to changes in the dioptric images or arise from some anatomic displacement of retinal elements is uncertain. That some kind of physiologic control through which the size and shape of the ocular images can be altered exists is evidenced by the behavior of a number of the clinical patients. Ordinarily, if the size of the image of one eye was changed by 0.25 per cent, a change could be seen in the displacement of the light points relative to the short lines. There were certain patients, however, to whom this did not apply. They seemed to have a capacity for keeping their ocular images of equal size while the dioptric image in one eye was made larger than that in the other. A typical example of this is a case in which the patient first showed no size difference. The interposition of lenses that increased the image in the left eye to 5.25 per cent caused no change in the position of the lights relative to the lines. A further increase of 0.50 per cent beyond that did, however, make the image in the left eye appear larger than that in the right.

Correlation of a Change in the Size and Shape of Ocular Images with Other Ocular Functions.—Granting the existence of physiologic processes that affect the size and shape of the ocular images, it would not be surprising if a correlation existed between the size and shape of

16. It has been generally held that no such change takes place. Investigation at this laboratory definitely indicates the contrary. See Ames, Ogle and Gliddon (foonote 14).

ocular images, accommodation and vergence. That such correlations do exist is indicated by the change in the size and shape of ocular images that takes place under the condition just mentioned. As yet a systematic study of the effect of a change of the size and shape of ocular images on accommodation and vergence has not been attempted. In a few preliminary experiments in which the images were changed asymmetrically in accordance with the Hering-Hillebrand horopter deviation, there appeared no immediate effect, although marked micropsia and macropsia phenomena were produced.

In clinical cases two types of behavior were observed that are of interest in this connection:

First, in examining the patients, size differences were determined for a distance of both 20 feet and 2.5 diopters. In a considerable number of cases it was found that the relative size of the patient's ocular images was different at the two distances.

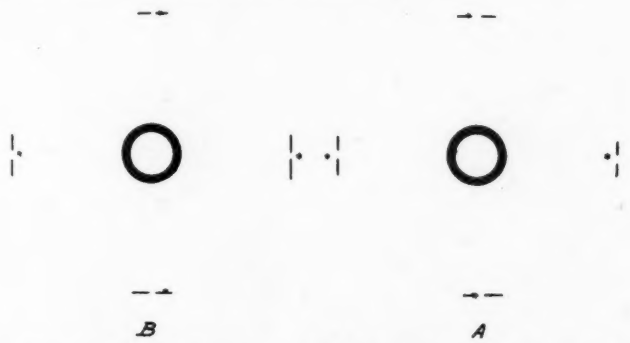

Fig. 14.—Appearance of targets in clinical instrument when "retinal slip" is present.

Second, in measuring the patients, their phoria condition was evidenced by what has been called "retinal slip," [6] that is, the displacement in the same direction of the points of light relative to the lines in figure 14. If the points of light seen with the right eye are to the left of the lines, there is an exophoric slip (14 *A*); if the points of light are to the right, there is an esophoric slip (14 *B*); if the points of light are above, there is a left hyperphoric slip; if the points of light are below, there is a right hyperphoric slip. It was found in a number of cases in which there were slight displacements of this kind that this retinal slip changed with the correction of size differences. This was especially evident with a slip in the vertical meridian.

Due to the apparent importance of "retinal slip," the following information relative to the phenomenon will be given: This so-called "retinal slip" in the horizontal meridian can be more accurately determined by the "grid nonius horopter" method, which has already been

mentioned. An orthophoric observer, in setting the dash and solid lines so that they appear continuous, will adjust the wires on a curve continuous with the fixation target (fig. 15 *a*). An exophoric observer will set them all behind the fixation target (fig. 15 *b*), and an esophoric observer will set them all in front of the fixation target (fig. 15 *c*).[17] The explanation for this, briefly, lies in the dependence of phoria on a phenomenon relating to the pointing of the eyes. With phoria the eyes are no longer pointing normally, but are diverged or converged, depending on the nature of the phoria.

This phenomenon was briefly described by Lau and Hofmann in papers dealing with binocular depth localization. Lau,[18] explaining a disparity that he found at the fovea, said: "It appears from this that in normal life we probably always assume an eye position that deviates from the mathematical convergence, and indeed the empiric line of

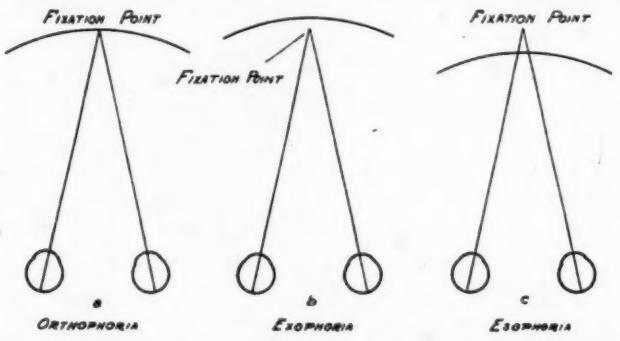

Fig. 15.—Position of grid-nonius horopter relative to fixation point with and without phoria.

regard of the two eyes is always directed to a point behind the fixated point." Hofmann,[19] dealing with the same phenomenon, recognized

17. These findings on horizontally heterophoric subjects are also of great interest from the point of view of our knowledge of the relationship between corresponding retinal points and the horopter. Heretofore it has been assumed that the horopter was determined by positioning a series of vertical threads or wires lying on both sides of the fixation point, so that they appear in a plane passing through the fixation point and normal to the direction of regard. On this assumption, such settings would give a measure of the relative position of corresponding retinal elements in the two eyes. Fischer (footnote 12) considered this assumption verified by using Tschermak's binocular-nonius method, which is in principle similar to our binocular-grid-nonius method. Measurements made in this laboratory on a large number of horizontally heterophoric subjects indicate, on the contrary, that apparent frontal plane horopter settings could give a determination of corresponding retinal elements only in the case of orthophoric observers and not necessarily then.

18. Lau, Ernst: Ztschr. f. Psychol. u. Physiol. d. Sinnersorg. (Abt. 2) **53**:1, 1921.

19. Hofmann (footnote 15, second reference, p. 428).

its correlation with the separation of accommodation and convergence. In the paper "Ocular Measurements" [6] from this laboratory, the same phenomenon is described under the name "retinal slip," and there its correlation to phoria is indicated. Later work in this laboratory on the determination of corresponding retinal points confirms this conclusion and definitely shows that with phoria there is a misdirection of the visual lines; that is, the focus of the fixation lines at the fovea falls on disparate retinal points.[14] The nature and magnitude of this disparity vary within limits with the nature and magnitude of the phoria, whether natural or induced by prisms or lenses. It is of interest to note that in the measuring of phoria the direction and amount of turning made by the eyes when they are disassociated is such as either to correct or to compensate for this disparity.

As generally understood, a phoria is only a tendency of the eyes to turn away from their normal position, an actual turning away taking place only after they have been disassociated; that is, phoria is supposed to exist only as a strain or innervational tendency, extrinsic to the ocular globes. The importance of these findings lies in that whatever may be the cause of phoria, it makes itself known by a derangement of visual impressions and not simply through extrinsic muscle strain or innervations.

Interesting questions arise. What induces this abnormal pointing of the eyes and the accompanying derangement of visual impressions? Is it simply a muscle pull or innervation to which the eyes respond by turning? Or does this misdirection exist only in respect to the fovea to satisfy some demand in connection with the proper positioning of other corresponding retinal points, such as conformity to a Hering-Hillebrand horopter deviation or an absolute size, distortion or some abnormal relationship in other meridians of the peripheral part of the retina? The word phoria, which means "tendency," does not seem most suitable to describe it, nor does the term "retinal slip," which we use. Possibly "fixation disparity" might be more suitable.

Difference in the Size and Shape of Ocular Images as a Disturbing Factor in Vision.—It may not be outside the province of this paper to suggest possible reasons why a difference in the size and shape of ocular images may have a disturbing effect on vision.

In general, it can be said that ocular images of different size may be disturbing because, with one eye indicating that a certain object is one size and the other eye indicating that it is another size, a visual conflict results as to the judgment of angular size. Further, a constant difficulty results, due to the tendency to fuse similar images exactly. When the images of one part of an object are fused, the images of the other part will not match, and vice versa. The unsteadiness of images and

the local suppresion so generally found in patients with a difference in the size of their images would seem to be evidence of this difficulty.

If account is taken of the part that a difference in the size and shape of the ocular images plays in binocular depth perception, more fundamental causes of discomfort become evident. As was shown in the experiment described, the position of objects in space as determined by binocular depth perception can be deranged by altering the size and shape of one ocular image relative to the other, such as when surfaces are rotated by a change in overall size in one eye. A person whose ocular image in one eye is larger than that in the other will always see his objective visual field rotated about a vertical axis at the point of fixation, that is, as he interprets it by binocular vision. But the positioning of objects in space is also made known in other ways, such as by touch and the monocular capacity for judging depth, particularly by perspective and parallax due to motion. As a result, a person with ocular images of different size will have imposed on his consciousness two conflicting interpretations. It would seem that such a state of affairs might well cause trouble. There is evidence that through experience a reinterpretation of false binocular perspective arising from differences in size of the ocular images is possible. But, even granting that such reinterpretation takes place, there would still remain a displacement of corresponding retinal points and their associated fusional areas which would mean a displacement of that area in space within which objects are seen singly.[13]

That differences in the size of the ocular images do in fact cause disturbances is evidenced by effects produced by wearing lenses that make the image in one eye different from that in the other. In a number of the clinical cases headaches and discomfort were produced by the wearing of wrong size corrections which were given by mistake. For further evidence, four members of the research staff and Mr. F. D. Comfort of Harvard University, who all had reasonably normal vision, tested the effect of wearing glasses that increased the overall size of one ocular image. Three of the five found the glasses very uncomfortable. In the case of one of us (Dr. Gliddon) a lens that increased the image in the left eye by 1.5 per cent produced a marked headache in about an hour. In Mr. Madigan's case, a lens that increased the image in the right eye by 3.0 per cent caused a slight headache after two days. A 4.5 per cent increase produced a marked headache. In Dr. Carleton's case a lens that increased the image of the right eye by 3.0 per cent gave him a slight headache and gastric disturbance, with dizziness and marked fatigue of the eyes. Mr. Comfort and Mr. Childs, on the other hand, suffered no discomfort from increasing the image of the right eye by 3.0 per cent. No systematic determinations have as yet

been attempted as to the effect of wearing such lenses for longer periods or as to the effect of changes in size in one meridian.

That differences in the size of the ocular images cause disturbances is also evidenced by a comparison of the size differences found in normal persons with those found in the clinical cases. Sixteen normal persons were measured to determine their size differences. Of this number, six had no size differences. The size differences found in the other ten averaged 0.85 per cent. The size differences found in ninety-six clinical cases averaged 1.54 per cent or almost twice as much.

In general, it can be said that associated with an abnormal difference in the size and shape of the ocular images there is a derangement of the space world as known from binocular vision. Moreover, all abnormal differences in the ocular images constantly make themselves known through disturbances in visual perceptions. There would naturally be an attempt to correct such differences through alterations of the size and shape of ocular images. As size and shape of ocular images are apparently correlated with other functions of the eyes, there is a possibility that they play a major rôle in the functioning of the eyes and may be responsible for at least some of the ocular conditions and abnormalities of functioning that are not now thoroughly understood.

THE CHEMICAL CONSTITUTION OF THE SCLERA *

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The knowledge of the composition of the structure of the normal eye is directly related to the interpretation of the physiology and pathology of the eye. The recent tendency in the chemistry of the eye has been to search for abnormalities in the aqueous and vitreous humors and in the lens, and to disregard the remaining ocular structure. But it must be remembered that the eye functions as an entire organ and that its tissues are physiologically interdependent.

The chemistry of the sclera, which is the most important ocular supporting tissue, has been incompletely investigated. Michel and Wagner [1] found 34.49 per cent solids and 0.867 per cent ash in the sclera, and Mörner [2] reported 0.84 per cent ash and calculated that the sclera contained about 13 per cent mucoid and 87 per cent collagen. Since the time of these reports, however, biologic chemistry has made remarkable progress in the study of tissues.

The purpose of this paper is to give the results of a reinvestigation of the chemical constitution of the sclera.

METHOD

Fresh ox sclerae were dissected free from all extraneous matter immediately after they were obtained from the slaughtered animal. They were scrubbed with a wire brush and washed quickly in cold distilled water to remove all external traces of blood and lymph. Any sclerae showing bloody exudations were rejected.

Water.—Sclerae freshly and quickly prepared without contact with water were dried at 105 C. to constant weight. The sclerae were not ground for the determination because of the impossibility of preventing loss of water. The average percentage of water in ten samples weighing about 10 Gm. each was 72.24, the minimum 70.32 and the maximum 73.05.

Inorganic Matter.—The incineration of these samples was performed in platinum crucibles in an electric muffle at a low heat until all the carbon was burned and the ash came to constant weight. The average percentage of ash, or inorganic matter, in the ten samples was 1.21, the minimum 1.03 and the maximum 1.37.

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* From the Wilmer Ophthalmological Institute, Johns Hopkins University and Hospital.

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2. Mörner, C. T.: Untersuchung der Proteinsubstanzen in den lichtbrechenden Medien des Auges, Ztschr. f. physiol. Chem. **18**:213, 1894.

Fat (Ether-Soluble Lipids).—Fresh tissue after drying was ground to a powder and dried at 105 C. to a constant weight. About 10 Gm. of powdered dry sclera was extracted in a Soxhlet apparatus with anhydrous ether until lipids were no longer obtainable. The average percentage of fat in ten samples was 0.261, the minimum 0.152 and the maximum 0.313.

Mucoid.—Freshly prepared sclerae were finely ground, extracted with water to remove albumin and globulin, and then extracted by stirring at 4 C. with 10 cc. of half-saturated lime water per gram of sclera for twenty-four hours. The suspension of tissue was removed by centrifugation. To the solution was added 1 per cent acetic acid until a maximum precipitation of the mucoid occurred on standing. The sclerae were repeatedly extracted until mucoid was no longer obtained. The mucoid, after it was separated from the solution, was redissolved in half-saturated lime water and reprecipitated with acetic acid. It was then washed with cold distilled water until the wash water gave no test for calcium and then extracted with alcohol and ether. To avoid decomposition, it was dried in a vacuum over sulphuric acid to constant weight as mucoid was partially decomposed at 105 C. in the drying oven. The average percentage of mucoid in ten

Chemical Composition of the Sclera

Constituent	Tissue	
	Fresh, per Cent	Dry, per Cent
Water	72.240	
Solids	27.760	
Inorganic matter	0.704	1.951
Organic matter	27.056	98.049
Mucoid	2.318	8.192
Collagen (gelatin)	22.139	81.045
Elastin	1.450	5.116
Albumin and globulin	0.561	1.612
Water-soluble extractives	0.516	1.823
Fat (ether-soluble matter)	0.072	0.261

samples of sclerae weighing from 100 to 500 Gm. each was 8.192, the minimum 6.82 and the maximum 8.79 per cent.

Collagen (Gelatin).—The mucoid-free sclerae were then washed with cold distilled water four times and with 0.1 per cent acetic acid until no test for calcium was given by the wash water. The sclerae were then washed until the water of extraction showed a p_H above 6.9. The mass of tissue was mixed with distilled water and heated at 95 C. for six hours. It was then centrifugated off and repeatedly extracted with water in the same manner until practically no reaction was obtained with tannic acid for gelatin. The gelatin solutions were concentrated by evaporation until they were viscous. After prolonged centrifugation to remove all finely suspended particles, the supernatant liquid was poured slowly with stirring into a large amount of 95 per cent cold alcohol. The fibrous gelatin was removed by centrifugation. It was redissolved in hot water, reprecipitated in alcohol, extracted with ether to remove any fats and water, dried and reduced to a fine white powder. The gelatin was estimated by difference. One direct estimation showed 97 per cent recovery of gelatin from the calculated amount of collagen.

Elastin.—The insoluble residue remaining after the extraction of the gelatin was an albuminoid which may be called elastin. This albuminoid was extracted with alcohol and ether, dried and ground to a light brown powder. The average percentage of elastin in the ten samples was 5.116, the minimum 4.83 and the maximum 5.64.

Albumin and Globulin.—Freshly prepared sclerae were finely ground by machine. The scleral tissue mixed with the tissue fluid from the ground sclerae was extracted with 10 cc. of distilled water per gram of sclera by continuous stirring at 4 C. for about two hours. About 100 Gm. of wet tissue was used for each determination. The aqueous extract was removed by centrifugation. The solution was then heated to give a temperature increase of about 1 C. in ten minutes to coagulate the soluble proteins. Coagula were obtained at from 53 to 57 C. and from 61 to 64 C. for globulins at from 71 to 73 C. for albumin. Five per cent sodium chloride extracts gave similar coagula. The average percentage of albumin and globulin was 1.612 in five samples.

Water-Soluble Extractive and Undetermined Substances.—After the albumin and globulin were coagulated, the solution was filtered, evaporated to dryness and dried at 105 C. to constant weight. The average percentage of water-soluble extractives of five samples was 1.823.

The complete analyses are summarized in the accompanying table.

COMMENT

The difficulties of the analysis of the chemical constitution were numerous. The eyes must be used at once because the tissues change chemically even at 4 C. through bacterial and enzymatic decomposition. The percentage of ash is not a true value of inorganic matter since the percentage of ash is increased by the presence of sulphates derived from the organic matter and organic sulphates. The mucoprotein was not easily obtained without a slight contamination with soluble protein, the amount of which was too small to be estimated. Methods using ammonium and sodium hydroxide produced changes in the protein of the mucoprotein. The elastin, on prolonged heating at a high temperature, possessed the tendency to form elastoses and lower degradation products which formed a part of the gelatin. Any reticulin present was changed to gelatin as it was easily hydrolyzed. The method used for the formation of gelatin from collagen was as mild as possible.[3] Gelatin was degraded or destroyed by excess or prolonged heating. The albumin and globulin probably came from the lymph and tissue fluids. Application of the analyses to the anatomy and physiology of the eye will be discussed in a later communication.

The material was furnished by Mr. R. L. Fox. Many of the technical procedures were performed with the assistance of Mr. Warren Tauber.

3. Buerger, L., and Gies, L. B.: The Chemical Constituents of Tendinous Tissue, Am. J. Physiol. **6**:218 (Dec.) 1901-1902.

Ophthalmologic Review

EDITED BY DR. FRANCIS HEED ADLER

RECENT ADVANCES IN THE CONSTRUCTION OF THE OPHTHALMOSCOPE*

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At the International Ophthalmological Congress at Amsterdam in 1929 a number of electric ophthalmoscopes were exhibited which were either unknown or little known in America. After examining these instruments and later temporarily possessing several of them it seemed that it might be of interest to supplement the excellent articles of Graves, Landon and Friedenwald and describe the advances in ophthalmoscopic construction in the last ten years. Several of my friends in foreign clinics have supplemented my own observations with their experiences with instruments that I have not personally used, and a number of manufacturers of ophthalmoscopes provided me with sectional drawings and particulars of the construction of the instruments.

The electric ophthalmoscope is readily divisible into several component parts, such as the observing lenses, light source, condensers, diaphragms, color filters, mirrors, measuring devices and slit-lamp illumination adjustments. Of all these divisions the viewing lenses have changed least. The Rekoss, or Loring, and the Morton arrangements remain most popular. Each fills its place and has proved satisfactory. So much cannot be said of the light source. The simple filament of earlier days has given way to a finely wound coil filament. In some instruments a gas-filled lamp is used. A variety of sizes prevail, from the minute globe of the May to the comparatively large bulb of the giant ophthalmoscope. In the latter, it has been realized that color filters, to produce adequate light of selected radiations, require an abundance of illumination. In hand instruments, a recent innovation is control of the illumination by a rheostat permitting a temporary overload.

The early ophthalmoscope had a single condensing lens sometimes so arranged that the brilliant electric filament could be focused on the retina. Today, almost without exception, both condensing and pro-

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jecting lenses are so included in an instrument that complete control of emerging rays from the light source can be obtained.

No lamp filament, however skilfully designed, can form an optical point of illumination, and this fact has led to the interposed diaphragm-screen between condenser and projecting lens, which forms a virtual source of illumination. In the same location color filters are usually introduced. By focusing the diaphragm aperture on the fundus or anterior chamber, point-light illumination is secured. In the same manner a narrow rectangular diaphragm produces a rectangular illuminated area resembling slit-illumination.

Mirrors of glass or steel show a change only in arrangement, some being attached in a manner to provide for increasing the interval between the illuminating and observing axes, and so attempt to carry out the principle of Gullstrand, that "the field of radiation of the illuminating system, and the field of radiation of the observing system must be completely separated in their passage through cornea and lens."

The invention of the Morgan retinal graticule, which projects squares of definite size on the retina, makes localization and linear measurement possible. Friedenwald has computed charts for use with the Gullstrand simplified ophthalmoscope enabling the observer to measure elevations exactly, and the true slit-lamp projector of illumination gives a definite idea of irregular fundus contour.

Binocular observation is achieved in one instrument, which can be equally well used for the ordinary or bed-fast patient, and Friedenwald made a definite advance when he corrected chromatic aberrations by interposing a crown flint doublet of opposite index from the eye itself and lessened spherical aberrations by placing small cylinder lenses in the axis of observation.

NEW INSTRUMENTS

A brief description of the various instruments includes only those that have been introduced during the past decade. Chronological order has been disregarded when grouping instruments of a similar type.

Of all the ophthalmoscopes described, the DeZeng giantscope undoubtedly is capable of emitting intense light. It is provided with a simple Loring head and has two semaphores, one containing a color screen to produce "red-free light," the other "daylight." They are located at the top of the tube close to the mirror and can be easily swung into position. The mirror is so placed that the observer can look over it and so gain a width of view unobtainable with instruments with a slot or small hole. The illuminating bulb is of a common type and mounted on a ball and socket joint which permits accurate adjustment. The superabundance of light is especially valuable for use with

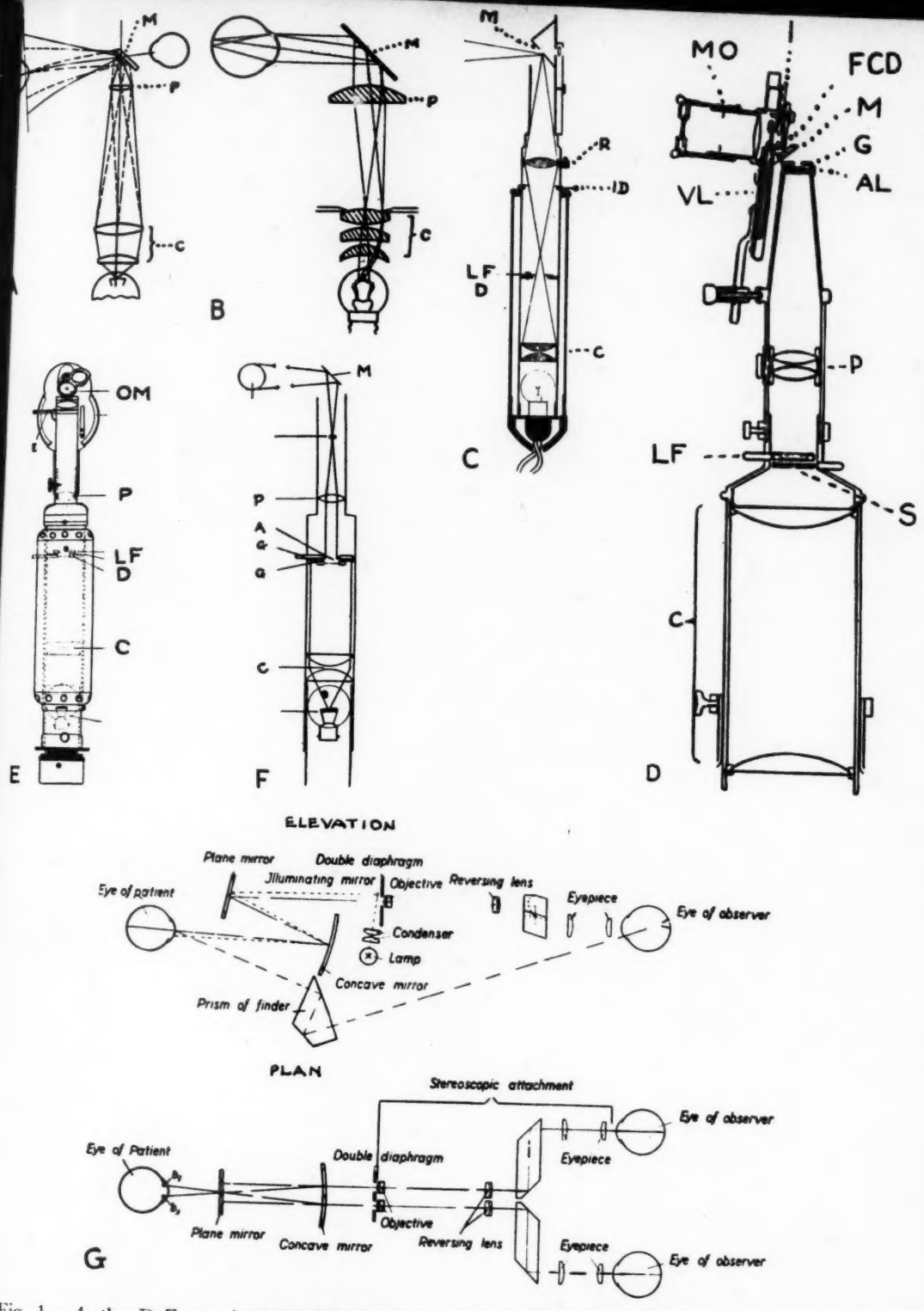

Fig. 1.—*A*, the DeZeng giant ophthalmoscope: *M* indicates the mirror; *P*, the projecting lens; the condenser. *B*, the Lister-Morton ophthalmoscope: *M* indicates the mirror; *P*, the projecting s; *C*, the condensers. *C*, the Fincham ophthalmoscope: *M* indicates the mirror; *R*, the refracting s; *ID*, an iris diaphragm; *LF* and *D*, the light filter and diaphragm; *C*, the condenser. *D*, the iedenwald ophthalmoscope (original model): *MO* indicates the magnifying ocular; *I*, the diaphragms; *D*, the flint crown doublet; *M*, the mirror; *G*, the diaphragm; *AL*, plus or minus auxiliary lenses; the projecting lens; *VL*, the Rekoss disk; *LF*, the light filter; *S*, the slit diaphragm, *C*, the con-sers; *E*, the Turville-Stewart ophthalmoscope: *OM* indicates the mirrors; *P*, the projecting lens; and *D*, the filter and diaphragm slides; *C*, the condenser; *F*, the Turville-Stewart ophthalmo-pe: *M* indicates the mirror; *P*, the projecting lens; *A*, *G* and *G*, the light filter and diaphragm es; *C*, the condenser. *G*, the hand stereoscopic Thorner ophthalmoscope.

the color filters. The voltage is too high to be obtained from a small battery and must be secured through a rheostat connected with an electric outlet.

The Cameron ophthalmoscope is about one-half the size of the instrument just described and has a Loring head with supplemental lenses that give a range from plus 23 to minus 24. The light source is a special Cameron bulb, and above it, at the focus of the condenser lens,

Fig. 2.—The Lister-Morton ophthalmoscope.

is a rotating disk containing filters for "red-free light," "daylight," a small perforation for illuminating a minute area of the fundus and a slit that can give a modified slit-lamp illumination to the anterior segment of the globe. A potential adjuster gives a range of current allowing a temporary overloading of the lamp when the color screen is used. Practically all adjustments can be made with the fingers of the hand holding the instrument while the observer views the fundus, and these, combined with the light weight and abundant illumination, are its principal advantages.

The Lister-Morton ophthalmoscope contains the Morton system of lenses, a battery handle and a sliding head by which one can vary the focus of the emerging rays. Although an examination of the diagram of the condensing system does not reveal obviously anything out of the ordinary, the result achieved by this system is unusual. The light from the objective is projected against a glass mirror which has a sight-hole in the center. The light rays are parallel or slightly divergent and succeed in passing through even a 2 mm. pupil so well as to enable the observer to study the macula in a fully lighted room. At no time does the patient complain of a sense of glare when the fundus is studied. The field of observation is evenly light, and fundus details are remarkably clear. An unusual feature is the octogon-shaped head of the battery-containing handle which effectively prevents the instrument from accidentally rolling. When the instrument is placed in its case, the head and the battery-containing handle separate and there is no possibility of a gradual loss of electricity through accidental contact. "Red-free light" is produced by slipping a filter over the illuminating tube.

The Fincham ophthalmoscope has its light source at the distal end of the handle of the instrument, increasing the interval between it and the reflecting mirror. The condenser is so located as to emit parallel rays to a stage containing a narrow slit aperture, and this is focused by another lens to the stainless steel mirror at the head of the instrument. An iris diaphragm is added to control the area illuminated in the fundus. The use of this permits exact control of the area of illumination. Beside this feature there is also a revolving screen carrying a "red-free" and a "yellow" filter. The latter, the makers state, is particularly useful when a certain amount of contrast is required in those cases in which the fundus is dark. For use as a retinoscope the lens that forms the image of the slit or diaphragm is swung out of the tube. The mirror is so arranged that the corneal reflex falls below the line of observation. The illuminating source is a nitrogen lamp requiring a current of 8 volts. The usual May disk of observing lenses is provided ranging from plus 25 to minus 20.

The Turville-Stewart ophthalmoscope has the Loring system of observing lenses, and the lamp with a straight spiral filament is mounted at the base of the handle. Means are provided for moving the lamp toward and away from the condenser lenses, and for rotating it on its axis so the filament and slit diaphragm are parallel for slit-lamp purposes. The adjustable distance is sufficient between the lamp and the condenser to permit, by changing the focus, an image of the filament to be produced at infinity or any point between infinity and slide-carrying platforms between the condensers and objective lens.

Into the slide-carrying platforms can be inserted a variety of diaphragms and color screens, as well as slits of different widths. Just below the observing lenses is another lens used only in slit-lamp observation. Two interchangeable mirrors are provided; one, for ophthalmoscopy, is a glass-silvered mirror with a central observation hole made by removing the silver; the second is a stainless steel mirror without holes for slit-lamp use only. The line of vision is above the latter

Fig. 3.—The Fincham ophthalmoscope.

mirror when in use. When properly adjusted, the lamp originates rays that are parallel when emerging from the condenser and remain so when they encounter the hole or slit before mentioned. This slit is the virtual source of illumination. The objective is focused on the slit and is of such strength as to converge the parallel rays. These rays reach the mirror and emerge as diverging rays. In the construction no light rays touch the side of the tube between the slit or diaphragm and the mirror, in this way getting rid of incidental rays. The instrument may be adjusted to use as a retinoscope.

The instruments described provide an abundance of light as well as light of selected radiation and some make use of a pinpoint diaphragm to illuminate a small area in the fundus and reduce the corneal reflex. None attempts to solve the problem of spherical or chromatic aberration, nor do any of them allow of true slit-lamp observation of the fundus itself. It remained for Friedenwald to solve these problems.

The Friedenwald ophthalmoscope was first publicly shown at the 1930 session of the American Academy of Ophthalmology and Oto-Laryngology. It contains a Loring-Rekoss system of viewing lenses in the head, and slots were added for small supplementary cylinders to neutralize or correct a patient's refractive error. There is also a flint-crown doublet which can be swung into position to correct the ordinary chromatic aberration of the observed eye. In this location also is a diaphragm with several apertures adjustable to the size of the pupil of the observed eye. A magnifying ocular is added, calculated to compensate for the spherical aberration of the normal pupillary zone of

Fig. 4.—The hand stereoscopic Thorner ophthalmoscope. *i* indicates the focusing band; *r*, a Rekoss disk; *s*, the finder prism container.

4 mm. so that the full benefit of magnification can, in most cases, be obtained. The light source is in the handle, and the light, after passing a compound condenser, reaches a platform as parallel rays. In the platform is a revolving disk having a slit and also an aperture for introducing a color filter. Above this is a compound objective which throws an image of the slit through an auxillary lens and diaphragm to the mirror. From this surface the light reaches the fundus. The focusing of the slit-image on the retina is controlled by moving the primary objective, and light can be thrown farther and farther down on the mirror surface until there is a separation of 15 degrees between the illuminating and the observing system. This arrangement also renders possible a near reflex-free observation of the fundus. The mirror is attached to the observing unit, and this can be moved sideways enough to include only a small part of the projected ray of light, reducing the amount of light thrown into the eye.

A new instrument, the Rodenstock prism refractometer, apart from its primary function, is capable of being used as an ophthalmoscope.

It permits a view of only 3.5 degrees at a magnification of × 15. The optic disk is the size of the entire field, and while detail is well seen considerable maneuvering must be done to cover much of the fundus. The iris must be dilated to permit extensive observation.

The original Thorner ophthalmoscope differed greatly in principles and construction from the instruments previously described as it not only eliminated the reflection of the cornea, but also had no internal reflection from the instrument itself. Mirrors were used largely instead of lenses in the construction of the instrument. The principle of illuminating the fundus through one portion of the pupil and observing

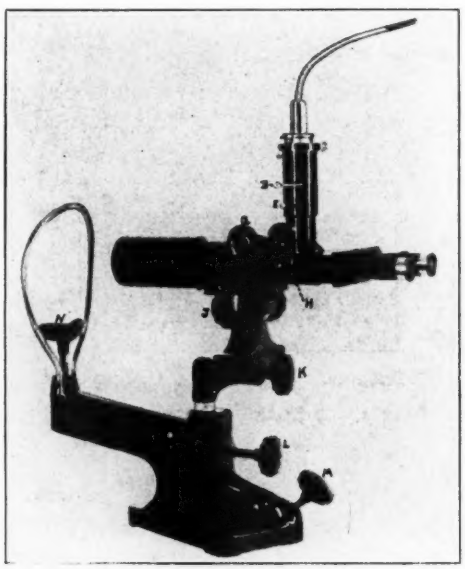

Fig. 5.—Large Busch-Thorner ophthalmoscope: *a* indicates a support for the illuminating tube; *b*, the illuminating tube; *c*, the main body; *d*, the glass window; *e*, the stereoscopic eyepiece; *f*, the light filter; *g*, the slit slide; *h*, an adjusting screw for the width of the slit; *i*, a focusing ring; *k*, a Rekoss disk; *l*, a focus for the slit edge; *m*, a fixation screw for the lamp; *n*, a side lever; *o*, an upward drive.

the fundus through another was accomplished by sending light through one half of the pupil only. The image of this half was then masked by a semicircular ocular plate. Observation was through the remaining half, a half moon-shaped aperture. A rubber cap attached to one end of the instrument, placed on the observed eye and fitting snugly, had the effect of a darkened chamber. The observer, looking through the eye piece, saw the fundus magnified four and one-half times.

but additional eye pieces permitted a magnification of from × 7 to 10. The observed eye fixed itself by looking at a small colored light. The whole instrument was to be revolved as different segments of the fundus were to be observed. Such is a brief description of the original Thorner ophthalmoscope.

Recently this design has been improved, and it can now be obtained as a binocular stereoscopic hand ophthalmoscope using the same system of illumination but possessing two sight-holes in the concave mirror that projects the light into the eye. As in the former instrument, there are no disturbing reflections. The linear magnification is × 16, and the image is inverted and appears in stereoscopic relief. The field of vision is 25 degrees. The instrument is designed for the special purpose of

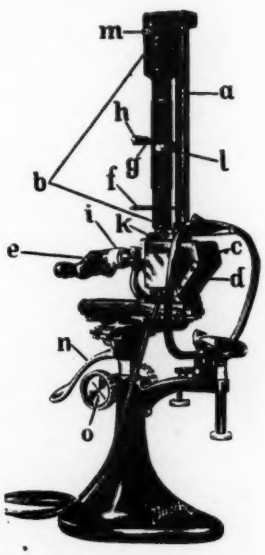

Fig. 6.—The Bausch and Lomb binocular ophthalmoscope: *D* indicates the moderating glass slide; *E*, the iris diaphragm; *G*, the focusing screw; *H*, the auxiliary viewing lenses for objective; *J*, a shifting screw—forward and backward: *K*, a shifting screw—right or left; *N*, the chin rest; *L*, a control for the height of the chin rest; *M*, a control for raising and lowering the whole instrument.

permitting stereoscopic examination of the eye that can be used equally well on patients sitting or lying down. The stereoscopic eye pieces permit a certain degree of adjustment to correct the refraction of the observer. There is also a prism finder. When in use the patient looks into the instrument at a green light with the right eye and at a red light with the left eye. The pupils are then exactly in the middle of the field of vision.

A third variation of this instrument is found in the large Busch ophthalmoscope (Thorner). This is of rather massive construction, somewhat resembling in size the large Gullstrand ophthalmoscope. For

use it should be placed on a heavy instrument table preferably with a cross-slide stand. The field of examination is 25 degrees, and the magnification is linear × 16. It contains three main units, the illuminating tube, the essential body and the stereoscopic examining appendage. It uses a nitra lamp of 6 volts and 4.35 amperes. This is mounted in the long illuminating tube where the emerging light is collected by lenses and sent into the body. There it is repeatedly mirrored, finally leaving the instrument in the form of radiating lines the transverse section of which has the shape of a narrow vertical line. This is focused sharply on the center of the pupil and permits the lines of observation to pass to the right and left of it. In the illuminating tube is a slide carrying a bluish filter absorbing almost fully the red; the second slide carries a gray glass, and the third a free aperture. Another slide has a free opening and near it an adjustable slit the width of which may be reduced to zero by means of an adjusting screen. An image restricted by an iris diaphragm of this slit can be projected on the fundus. The examiner thus has red-free or red-poor light and also means for illuminating slit or sharply limited areas showing clearly minute differences in the level of the retina or choroid.

The new Bausch and Lomb binocular ophthalmoscope resembles, in general principle, the simplified Gullstrand instrument with the important difference that the stative or head rest is a part of the ophthalmoscope proper. For this reason the relative position of the eye under examination and the instrument are easily and quickly adjusted. Added to this is the remarkable ability to secure binocular observation of the fundus through a 2.5 mm. pupil. The magnification is × 10, permitting a wide view of the fundus. A magnification of × 20 can be secured by the use of an extra pair of oculars. Corneal reflexes have been eliminated by proper design. For considerable refractive errors of the patient, auxiliary lenses are provided, compensating for refractive errors from —20 to +20 diopters. Should the intensity of illumination be too great, it can be reduced by a slide carrying a moderating glass. Further reduction of intensity is obtained by an iris diaphragm. The closing of this diaphragm also cuts down the size of the field, which is often advantageous when studying one particular portion of the fundus without discomfort to the patient.

Recently three new ophthalmoscopes have been announced in the *British Journal of Ophthalmoscopy*. The first, the Anumbra-Morton ophthalmoscope (Clement Clark, Ltd.), uses a prism rather than a mirror for a reflector, and the claim is made that the shadow ordinarily seen at the bottom of the field with a prism instrument, when adjusted for direct ophthalmoscopy, is not present. The improved illumination

is accomplished by special attention to the light source, optical system and axis of observation. At the same time the corneal reflex is reduced and decentered relative to the axis of observation. The second instrument is the Keeler Decagon ophthalmoscope (C. Davis Keeler), which provides for ophthalmoscopy, both direct and indirect, point illumination of the fundus or anterior chamber, linear measurements on the retina with a Morgan retinal graticule, estimation of refractive error by projecting the graticule on the retina and red-free and artificial daylight illumination. The third instrument is the Morton ophthalmoscope and retinoscope (Rayner) with a red-free and a red filter. More complete data concerning these instruments cannot be obtained at the present time owing to the fact that they have been so lately introduced.

The Polyophthalmoscope of Zeiss for multiple observation of the fundus is based on the same principle as the simplified Gullstrand ophthalmoscope plus the arrangement for multiple observation. It is purely a teaching instrument and, while a scientific achievement, cannot be included with the instruments described.

COMMENT

From such an array of new instruments, a few will come into more or less common or popular use. Convenience in handling, an evenly illuminated field, with an excess of light for use with color filters, a true slit-lamp projection, binocular observation and last, but not least important, an ability to permit observation of a maximum field through a minimum pupil will be the deciding factors. All are desirable, but their relative importance will vary with each user. It is my hope that at some future time it may be possible to assemble, permanently, all recent models of ophthalmoscopes in a central location so that if one has the inclination or desire to investigate seriously an instrument one may individually, by use, become acquainted with the excellencies and the short-comings of each ophthalmoscope.

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Clinical Notes

FORCEPS TYING OF SUTURES*

WALTER S. ATKINSON, M.D., WATERTOWN, N. Y.

This easy, simple and aseptic method of tying sutures with forceps is shown, not as something new, but as an adaptation for the ophthalmic surgeon of a similar method used by the general surgeon. Simplifying and perfecting each step of any operation shorten the duration and increase the percentage of good results.

Fig. 1.—The forceps used.

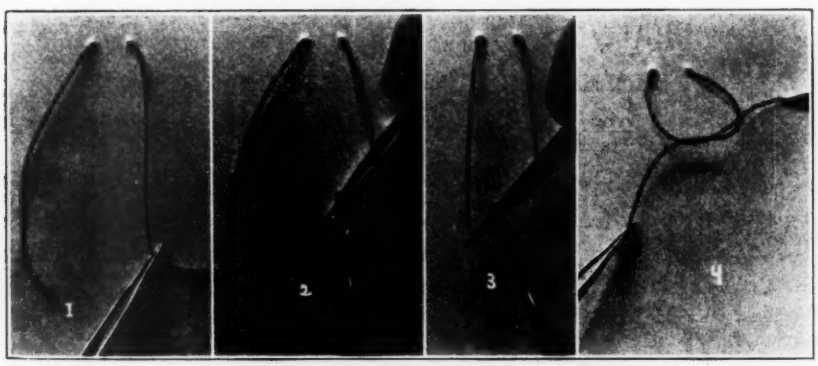

Fig. 2.—The method of tying the sutures.

The forceps used are a little different from the ordinary small tissue forceps. Instead of the blades having just the horizontal serrations, there is a cross-hatching that prevents the smallest suture material from slipping, regardless of the angle at which it is grasped. With the ordinary tissue forceps, if the suture material is not grasped at a right angle to the serrations, or nearly so, it slips through. Then, too, the tips are straightened somewhat so that they come together in close apposition for one-half inch, giving a much longer surface for grasping the suture material. The forceps are also satisfactory, as a needle driver, for conjunctival suturing.

* Submitted for publication, Dec. 11, 1931.

Comparatively short sutures are used, those 6 inches long being ample in most instances. The advantages of using short sutures are: (1) they do not extend far from the operative field, and are less likely to become contaminated, and (2) they are more easily tied.

The method of tying is shown in figure 2; very heavy thread was used for clarity.

Step 1.—The forceps in the left hand grasp the end of the suture on the right and draw it toward the end of the suture on the left.

Step 2.—The right end of the suture is then wound one turn around the forceps held in the right hand.

Step 3.—The forceps in the right hand then grasp the end of the suture on the left and draw it through the turn that was made on the forceps.

Step 4.—The first half of the knot is then drawn tightly and a second tie made in the same manner to complete the knot, except that the suture is wound around the forceps in the opposite direction in order to make a square knot.

To tighten the knot, when suturing about the eyeball, it is not advisable to continue to hold the ends of the suture on account of undue traction, but a new hold should be taken nearer the tie.

In tying skin sutures, when the element of traction is not of importance, the first tie may be completed without letting go of the ends of the suture; then only one end is dropped, preferably the right, and the second tie is made as described.

PERIMETER SPOT-LIGHT OBJECT*

JOHN N. EVANS, M.D., BROOKLYN

Ophthalmologists who are interested in encouraging scientific perimetry have felt that moving objects by means of wires or cards not only is time-consuming, but also is sure to distract the patient's attention, particularly when the objects are worn. It is not always possible to make the theoretically approved technic practical for clinical studies, but an electric spot-light object has been devised which approaches the ideal. This has been in use in various forms for the last three years, and though no claim for originality is being made, the combination suggested seems not to have been used in the way described. To all intents and purposes a small slit-lamp has been constructed which projects a disklike spot of light on the arc. The size of the object can be varied by turning a small wheel, and its intensity and color can be modified by appropriate filters. The projection device is suspended on a swivel from the center of curvature of the arc, beneath the source of illumination, as on a Ferree-Rand perimeter.

* Submitted for publication, Jan. 14, 1932.

* From the Research Laboratory, Brooklyn Eye and Ear Hospital.

The operator stands alongside the patient and, grasping the projector by an appropriate handle, can switch the spot on and off at any point along the arc. This device reduces materially the necessary time expended. Quantitative field studies with three sizes of object can be completed on one eye in ten minutes' time. This allows twenty minutes for complete studies of the fields in a complicated case, such as a tumor of the brain. As twenty minutes is usually the average length of time for office appointments, it is practical to have the patient come specially for this study. Following is a description of the instrument, its method of manipulation being obvious.

THE APPARATUS

The source of illumination is a Zeiss slit-lamp bulb (fig. 1 *A*) which is screwed into the socket (fig. 2 *Z*) provided with the Zeiss slit-lamp. This socket may be purchased separately from the slit-lamp and is pro-

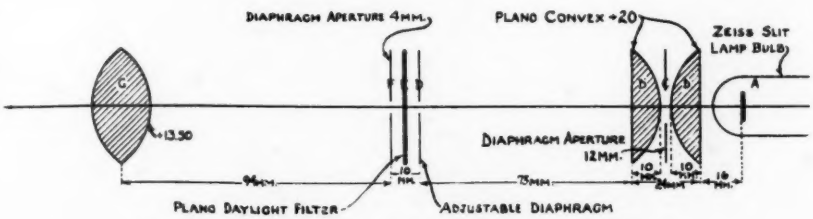

Fig. 1.—Optical system for the spot-light object.

vided with centering screws so that the filament may be moved up or down, right or left, as necessary. A brass tube (fig. 2 *Y*) 50 mm. in diameter is procured, into which a second brass tube (*X*) is fitted in such a way as to slide back and forth, receiving at its proximal[1] end the slit-lamp bulb socket described. The outer tube should measure 170 mm. in length; the inner tube, 50 mm. The purpose of the inner tube is to permit the slip-lamp bulb to be slid back and forth longitudinally along the optic axis of the projector. A lens system is centered within the outer tube. This lens system is composed of three units. Two + 20 planoconvex lenses (fig. 1 *B* and *B'*) are mounted with their convex surfaces facing each other, in such a way that the plane surface of one is 24 mm. from the plane surface of the other. Between the two convex surfaces a diaphragm (*C*) is inserted which contains a circular aperture 12 mm. in diameter. This lens system is then fixed in the outer tube (fig. 2 *Y*) of the projector in such a position that the plane surface of the proximal lens is centered 16 mm. in front of the centered filament of the light source. Seventy-five millimeters distal to the distal sur-

1. Proximal means the end of the projector that stands nearest the patient.

face of this lens system a rotating diaphragm (*D*) is so arranged that by turning it a graduated series of circular apertures may be brought into the axis of the optical system. The diameters of these apertures are 0.10, 0.18, 0.31, 0.42, 0.95, 1.30, 1.60 and 1.85 mm. Their respective images, when projected on the arc, measure 0.75, 1, 1.5, 2, 3, 4, 5 and 6 mm. in diameter. A click spring fixes the aperture in the optical axis as it is turned by the finger of the operator. The edge of the rotating diaphragm is marked to indicate the size in millimeters of the projected spot. Immediately anterior to this adjustable diaphragm a carrier is provided which will allow the insertion or removal of a "daylight blue" glass filter (*E*) of such density as to approximate most nearly natural daylight in color. Smoked glass or color filters should replace the daylight filter when occasion demands. Ten millimeters

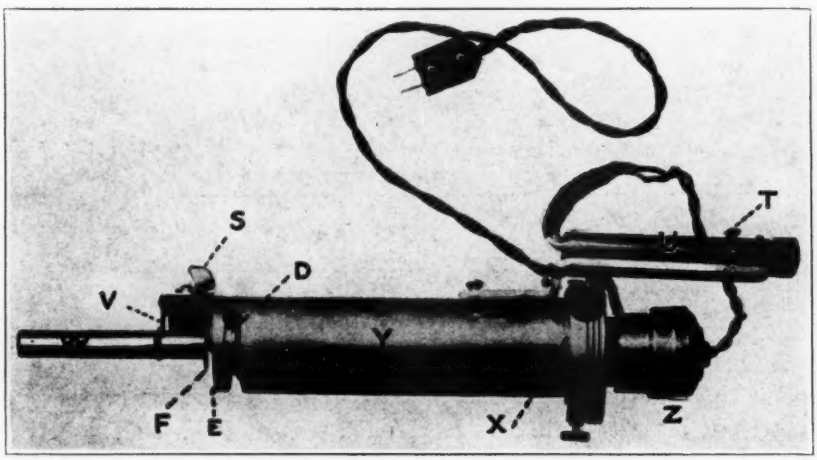

Fig. 2.—The external appearance of the spot-light object and switch.

distal to the adjustable diaphragm a fixed diaphragm (fig. 2 *F*) is placed in the small tube (*W*), having an aperture of 4 mm. The smaller tube (*W*) measuring 12 mm. in diameter by 93 mm. in length, is next mounted by means of an adjustable bracket (*V*) on the large tube in such a way that its long axis is in line with the optical axis of the system. In the distal end of this tube a + 13.50 double convex lens (fig. 1 *G*) is mounted 94 mm. from the face of the last aperture (*F*), closing the large tube. This assembled system then constitutes the projector. It should be mounted directly under the center of the source of illumination of the Ferree-Rand perimeter by means of a ball and socket joint, so that it may be moved in any desired direction. This ball and socket joint is located 110 mm. from the distal end of the projector. The distal end of the tube (*Y*) is provided with a catch hook (*S*) to support the spotlight object against the illuminating lamp housing when the perimeter is not in use. The overall length of the projector is 340 mm.

On the large projector tube at the proximal end and immediately over the lamp housing (fig. 2) a Burgess vacuum contact switch[2] (*U*) —size 6—is mounted on a tubular brass housing. The glass handle of this switch is supported by a spiral spring in such a way as to keep the contacts within the vacuum separated. Opposed to this spring a small button (*T*) is mounted through the housing of the switch in such a way that pressure on it will neutralize the action of the spring and

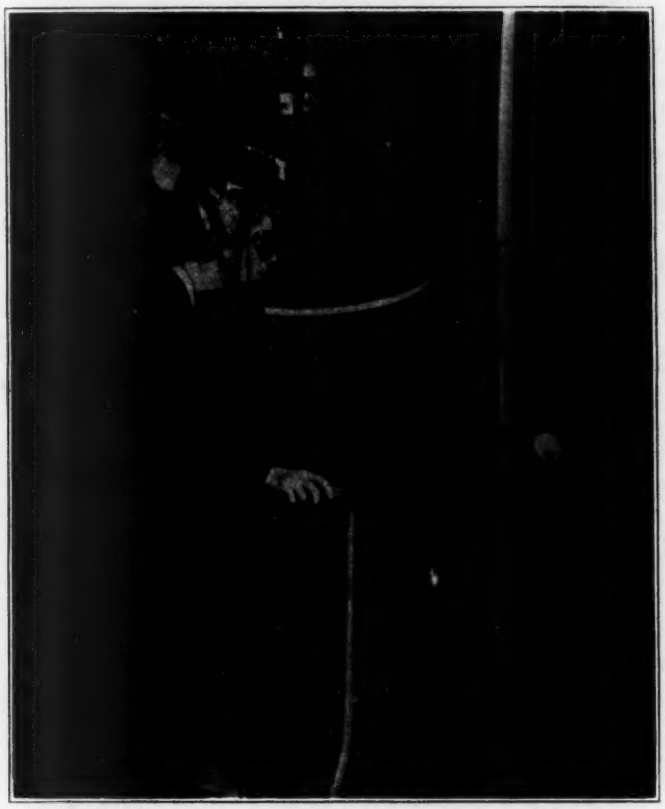

Fig. 3.—The method of using the spot-light object as mounted on the Ferree-Rand perimeter illustrated with a type of switch discarded in the present model.

permit the approximation of the contacts within the vacuum chamber. This switch is noiseless, and the contacts will not burn out when rapidly closed and opened, because the vacuum disposes of the intense spark ordinarily produced in other forms of switches when the slit-lamp bulb is operated through a large rheostat. It is necessary to obtain the rheostat through the Zeiss Company, or to supply similar suitable resistance mountable on the perimeter table. The whole unit is then wired in

2. This switch can be purchased only through the Burgess Battery Company, at any of their many branches.

series. A special iron bracket with a band-clamp must also be provided to mount the projector beneath the light source of the Ferree-Rand perimeter, as indicated by figure 3. It is necessary in some models to modify the shield and reflector attached to the light source of that device. The rheostat must be set so that the filament is very much overloaded, in order that as intense a light as possible may be obtained. The brightness of the perimeter arc and the brightness of the projected 6 mm. spot of light must then be measured by a suitable photometer, and this measurement must be repeated after the bulb has become seasoned by a few days' use. These precautions thus standardize the factors that influence surrounding field and preexposure. They also set the brightness of the object and background at the same level for subsequent examinations.

NOTE.—Measurable reduction of the brightness of the object is also attainable by slipping a cap (a smoked glass filter) over the distal end of the projector, thus enabling one to detect the early changes of glaucoma in the peripheral fields. It is necessary under some conditions to derive the current for the spot-light object from a source different from that supplied the arc illuminator, as the sudden switching on of the current may otherwise produce a flicker in the arc illumination. A separate "riser" from the house meter may attain this object.

ADVANTAGES AND DISADVANTAGES OF APPARATUS

The main advantages of this form of perimeter object may be listed thus:

1. Standardizable size, color and brightness of objects are obtained.
2. Rapidity of field taking is increased.
3. Scientific demands are adapted to clinical routine.
4. Freedom from distortion is accomplished.
5. Freedom from shadows and reflexes is secured.
6. Colors and decreased illumination are accurately controlled.
7. Neutral gray is a satisfactory arc color for white and colors; a black arc is also satisfactory.
8. It is practical to so adjust the brightness of the spot projected that it compares accurately with the reflection factor of the usual paper disk objects.
9. Field studies as made with the spot-light objects are identical in result to those mapped under parallel conditions with the usual paper disk objects.

The disadvantages of this device may be cited:

1. The original cost is expensive.
2. It has a formidable appearance to the patient.
3. Though the reflection factor is the same as that of the classic objects, and though the fields mapped with the spot-light object are

identical in size and shape with those mapped with the white disks, there may be theoretical objections that they are not identical as stimuli. One should keep in mind, however, that there is no such thing as a perfect white. It has been said that the whitest known substance is pure calcium sulphate. I might suggest that "dental plaster of paris" would be a good coating for the paper disk objects.

23 Schermerhorn Street.

A SERIES OF RADIUM INJURIES TO AN EYE*

ARNOLD KNAPP, M.D., NEW YORK

Extensive injury to the eye has been particularly observed when skin lesions of the eyelids were too freely treated with radium, especially at a time when the danger to the eye from this treatment was not recognized. The ocular changes in the case to be described occurred in this way.

A woman, aged 31, was first seen in October, 1915, on account of a central choroiditis in the right eye which reduced her vision to fingers at 3 feet. The left eye, which was normal, presented an area of skin eruption at the outer canthus, of twelve years' standing, which had resisted all forms of treatment. In 1920, this area was treated with radium by an expert, which resulted in its healing. In the following year the left eye began to show some irritation, and in the course of the next years various changes occurred in the eye. In 1922, a faint opacity developed in the posterior cortex of the left lens. This cortical opacity gradually increased, and numerous punctate opacities developed on the temporal side of the lens. The irritation of the eye varied, but frequently the patient suffered a great deal of photophobia, so that on certain days she could not go into the light, or go out of doors; there was a constant dryness and tightness of the eyelids; in fact, she had not wept with this eye since the radium treatments. The conjunctiva had become changed to an epidermoid tissue; it was blanched and like keratosis. The surface of the cornea was dry, and the magnifying glass revealed many faint dots or stipples which stained with fluorescein. Sensation was reduced.

In the meanwhile the cataract slowly developed, and as this was the only good eye an operation had to be undertaken, though in view of the conditions present, not without considerable misgiving. A preliminary iridectomy, an extraction with capsulectomy and needling were performed, fortunately with a good final visual result, namely, 20/20. The only complication was an extraordinary behavior of the conjunctiva and cornea in the area of the incision, after the preliminary iridectomy, and still more so after the extraction. This change consisted of a glassy

* Submitted for publication, Jan. 19, 1932.

* Presented at a meeting of the New York Academy of Medicine, Section of Ophthalmology, Jan. 18, 1932.

transformation, an intensely white nonvascular, opaque thickening of the conjunctival flap (the conjunctival vessels stopped abruptly at the margin of the flap), and the line of the incision was a somewhat broadened, hyaline, translucent linear gap. Fortunately, the closure of the incision seems to be secure, the tension is normal and the patient has no symptoms beyond those caused by the previous conjunctival and corneal conditions which are unchanged.

Rohrschneider [1] said that the injuries to the conjunctiva from radioactive rays are vascular changes which appear late: telangiectases, glassy swelling (Birch-Hirschfeld) and distention. The vascular changes histologically present the picture of vacuolizing endothelial degeneration, and in addition, epithelial changes have been observed like keratosis, leukoplakia and shrinkage (Michail, Onfray, DuPuy-Dutemps, Treacher Collins). The conjunctival vascular changes do not occur alone, but are evidences of intense radio-activity and are associated with corneal changes, cataract and glaucoma. The corneal changes consist in hypesthesia, various forms of superficial keratitis, ulcers and diffuse opacities. Cataract is a late manifestation and appears as a posterior polar opacity resembling the glassblower's cataract.

The changes that occurred in the foregoing case are thus readily explained, except for the curious healing of the cataract incision and the cessation of the lacrimal secretion.

I am unable to find a reference to any complication in the healing after extraction of cataract caused by radium, and in the few cases in which I have had to operate for this condition, the operation and healing were uneventful. The changes in the area of the conjunctival flap and scleral incision must be the result of vascular changes which radium causes. Fortunately, the eyeball has not been injured, and glaucoma has not developed.

The cessation of the tears may be due to the cicatricial changes of the conjunctiva in the region of the lacrimal ducts, or to direct atrophy of the lacrimal gland from the action of the radium.

In this connection, it is not without interest to draw attention to the roentgen treatment of the lacrimal gland to arrest the tearing which persists after removal of the lacrimal sac. This treatment has been used by Brandt and Fränkel [2] and by Henson and Lorey; [3] the eyeball is protected with a lead glass shell, and no injury to the eye has been observed.

Within recent years the removal of the lacrimal gland has sometimes been followed by a peculiar dry catarrh, with tenacious thread-like mucus, superficial corneal erosions and filamentary keratitis, which have been ascribed to cessation of the tears.

In the foregoing case, it is difficult to decide whether the corneal changes were due to the action of the radium or to the lack of tears. I am inclined to hold the direct action of the radium on the cornea responsible.

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1. Rohrschneider: Schädigungen des Sehorgans bei therapeutischer Anwendung von Röntgen und Radiumstrahlen, Ztschr. f. d. ges. Ophth. **23**:289, 1930.
2. Brandt and Fränkel: Deutsche med. Wchnschr. **48**:159, 1922.
3. Hensen and Lorey: München. med. Wchnschr. **69**:1573, 1922.

News and Notes

EDITED BY DR. JOHN HERBERT WAITE

GENERAL NEWS

George Strong Derby Memorial Fund.—The desire has been spontaneously expressed among the friends and patients of the late Dr. George S. Derby that a fund be created by donations, the principal to be kept intact, and the annual income to be applied under the direction of the Board of Surgeons and the Board of Managers of the Massachusetts Eye and Ear Infirmary to continue projects fostered by Dr. Derby. Among other things, it is desired to continue and to widen the application of medical social work to eye clinics, and to provide instruction for medical social workers. Contributions to the fund should be directed to Mr. James Dean, Treasurer, 201 Devonshire Street, Boston, and should be plainly marked "for the George Strong Derby Memorial Fund."

Conservation of Vision, Philippine Islands.—Statistics collected by a committee on the conservation of vision, created by the house of delegates of the Philippine Islands Medical Association in 1927, showed that the blindness and defective vision prevalent among Filipinos could often be prevented by proper care. Of 1,800 cases of blindness studied, 27 per cent were caused by cataract and 25 per cent by physical injuries improperly treated. Of 7,996 industrial accidents, 222 involved the eyes. Though goggles are recommended, they are not required by law. The committee intends to feature popular education, enforcement of regulations concerning communicable disease, establishment of more eye clinics in the provinces and instruction of medical personnel. The committee sponsored legislation (which is still pending) requiring the use of preventive measures against ophthalmia neonatorum. Dr. Antonio S. Fernando is chairman of the committee, and the members are Drs. Rafael Villafranca and Conrado D. Ayuyao.

Ophthalmic Examination.—The American Board for Ophthalmic Examinations will hold an examination in New Orleans on Monday, May 9, 1932, at the time of the meeting of the American Medical Association. Applications for this examination should be procured from the secretary, Dr. William H. Wilder, 122 South Michigan Avenue, Chicago, and should be sent to him at least sixty days before the date of the examination.

SOCIETY NEWS

North Dakota Academy of Ophthalmology and Oto-Laryngology.—The mid-winter meeting of the Academy was held in Fargo on Feb.

13, 1932. Dr. A. D. Prangen of the Mayo Clinic addressed the Academy on the following subjects: the early management of strabismus, the operative treatment of strabismus, and problems and procedures in refraction.

PERSONAL

Dr. Charles A. Bahn has been appointed professor of ophthalmology in the Post-Graduate Department, Medical Division of the Louisiana State University.

Correspondence

THE MECHANISM OF ACCOMMODATION

To the Editor.—May I venture to make some comments on Dr. Luedde's interesting paper on "The Mechanism of Accommodation," published in the January issue, page 40.

A. First of all, I think from a study of much literature and many pictures, that the anterior extremity or "origin" of the ciliary muscle is very near Schlemm's canal. Its tendon of origin may, according to Arthur Thomson, influence the lumen of Schlemm's canal. The circular portion of the muscle during life is probably *in* the plane of the equator, being situated behind the root of the iris.

It is even possible that the anterior extremity of the muscle may be connected with the dilatator muscle of the iris.

Only a part of the ciliary muscle, therefore, lies *behind* the plane of the equator of the lens.

B. Second, with regard to zonular relaxation in accommodation, nearly all authorities are agreed, except Mawas, Merigot de Treigny and Bernard. Cattaneo, whose recent study of aniridia is very clear and illuminating, showed that tremor of the lens may occur without the use of physostigmine (eserine) at ranges of 10 or 15 cm. focal distance. He decided that the movements of the lens (sagging, Liusenschlottern) observed in extreme accommodation are certainly due to zonular relaxation, and he does not suggest that they are of vitreous origin.

His observations are in harmony with those of Graefe, Grossman, Story, Terrien, Fincham, A. L. Browne and Hess.

I regret that Dr. Luedde does not refer to Hartridge and Yamada's very careful study of the cat's lens, which tends to show that the flattening of the periphery of the anterior part of the lens is relative and not actual, and that the *dioptric power* of the extracted cat's lens resembles that of the fully accommodated lens in situ.

They thus confirm Helmholtz.

C. As regards the lens substance being nonelastic, there may be some vital elasticity, in the nucleus at any rate, since living protoplasm is elastic. Donders states that the lens, *in its capsule,* is elastic. "On gentle pressure its form is easily altered, but it immediately regains its original form when the pressure ceases."

Donders' account of accommodation is scrupulously fair. He considers that the origin and insertion of the ciliary muscle are both elastic.

D. That the vitreous is passively accommodative seems highly probable. In this connection I note a curious statement in Macalister's textbook on anatomy, namely, "that the interspaces between the zonular fibres in the circum-lental space are occupied during life by a semi-fluid forward extension of the vitreous."

E. If the lens substance is not elastic, is it not possible that when zonular relaxation occurs the anterior surface of the lens may advance forward for two reasons?

1. The line of zonular attachment shifts inward centripetally, and the subjacent lens substance shifts with it, being (presumably) *adherent* to the capsule along this line.

2. When the line of zonular attachment shifts thus, the *capsule* within this reduced circle must be much relaxed, so that a *potential vacuum* would tend to form between the capsule and the lens substance at the anterior pole of the lens. As it is impossible for actual discontinuity to occur, the lens substance *must* "flow" forward, as it were, to fill up the slackened capsule.

F. As regards the mystery of the circumlental space, one is dependent on observations of pathologic and traumatic cases. Cattaneo shows that in his case 5 reduction of the transverse diameter of the lens does occur.

One must, I think, regard accommodation as brought about not solely by lenticular changes, but by *cooperative movements of every mobile structure* within the eyeball.

G. The zonular tension theory of Tscherning is supported still by patriotic Frenchmen, but would have been discarded long ago were it not for the brilliance of its author and for a certain obscurity as to the action of the radial or transitional fibers of the ciliary muscle. Thomson-Henderson thinks that these radial fibers tense the zonula.

If one considers the ciliary diaphragm as contracting and dilating like the iris, such *analogy* seems to me helpful in explaining accommodation. The ciliary muscle should be considered as a whole and stereoscopically, and not merely in sectional views.

I cannot agree that the posterior meridional zonular fibers are not relaxed in accommodation, nor that the ciliary body is incapable of movement on the sclerotic. The uveal tract is certainly not bound down at the ora serrata in man.

The zonula may be regarded as an aponeurosis, which must be influenced by the movement of the muscle beneath it, even as far back as the ora serrata.

H. Though the hydraulic theory of accommodation is supposed to be "put out of court" by the phenomenon of "Liusenschlottern," I think this theory is deserving of further study.

I. No one can fail to be profoundly impressed by Gullstrand's account of accommodation. It is wonderful.

Nevertheless, one may venture to make some diffident criticisms.

1. That there is "no difference of pressure" during accommodation, on either surface of the lens, seems to me improbable.

Such changes of pressure, and adjustments so delicate, cannot be measured in the living eye by the crude methods at one's disposal. There must be ebb and flow of aqueous and vitreous.

2. Gullstrand's "intrinsic mechanism" is not as clearly explained as it might be. What causes the shifting of the filaments of the lens?

3. It is not certain that freezing is responsible for the shape of von Phlugk's series of lenses. While greatly admiring these photographs, I do think that freezing is not an ideal method for estimating these changes.

4. It seems to me improbable that *cocaine* would cause the anterior lenticonus observed by Tscherning, Besio and Fincham. It may be an individual peculiarity and not invariable in all eyes.

Is it not possible that the relative flattening of the margin of the lens in extreme accommodation is really due to the very thick marginal capsule in front and behind, which does not permit it to expand anteroposteriorly but does permit centripetal shifting of the equatorial lens substance?

I conclude from Dr. Luedde's paper that the fibers of the fresh lens have been stretched under the microdissection microscope and *proved* to be nonelastic. Was the nucleus investigated? When, where and by whom was this work done?

REGINALD A. YELD, M.D. (CANTAB.), Edgewood, B. C.

Abstracts from Current Literature

EDITED BY DR. WILLIAM ZENTMAYER

Anatomy and Embryology

THE MICROPHYSICAL STRUCTURE OF THE RETINAL RODS. A. STILO, Ann. di ottal. e clin. ocul. **59:** 630 (July) 1931.

Previous work on the histology of the rods is reviewed. In the inner elements of the rods especially, great differences are observed according to the fixative employed. The author examined dissections of the fresh retina of an amphibian, Discoglossus pictus, by means of ordinary microscopy and dark-field illumination. In fresh preparations the membrane of the rods has a luminous appearance, while the substance within this is homogeneous. After longer observation, the outlines of disks, which become granular, separated by homogeneous interspaces, become evident. This phenomenon the author interprets as a colloidal change, the substance in solution becoming "unmixed" from its solvent and the disks representing the type of gel formation which occurs in coagulation of the blood plasma. The granules observed after staining or reducing methods were not seen in fresh preparations.

S. R. GIFFORD.

THE MORPHOLOGY OF THE NEUROGLIA IN THE OPTIC NERVE AND RETINA AS REVEALED BY THE METHODS OF THE SPANISH SCHOOL (RAMÓN Y CAJAL). C. O. BULAC, Ztschr. f. Augenh. **74:** 248 (June) 1931.

By staining sections of the optic nerve, chiasm and retina with stains advocated by the Spanish school, Bulac noted that human, goat, sheep, ox and rabbit eyes have a similar structure. The author observed that del Rio Hortega's technic is the most satisfactory for the study of neuroglia, and that it gives the best promise for the solution of doubtful problems concerning the structure of this tissue. By the addition of a small amount of hydrochloride or acetic acid to the fixing bath when ammonium bromide is used as a fixative fluid, Bulac obtained better results. The observations made are in accord with those recorded by Marchesani. By staining the retina with gold sublimate according to the method of Ramón y Cajal, the author demonstrated astrocytes in the tissues; by using Hortega's stain, Mueller's supporting fibers were found.

A. M. YUDKIN.

STUDY OF THE GLIA IN NORMAL AND PATHOLOGICAL RETINAE AND OPTIC NERVES. MOTOHARU ISHIGURO, Acta Jap. Ophth. Soc., August, 1931, p. 109.

For interpretation of pathologic changes in the retina and optic nerve, it is important that the normal morphologic and pathologic changes that the glial tissue undergoes are well understood.

The author examined this problem in the eyes of man and of rabbits employing specific fixatives and frozen sections, and demonstrated three forms of glial cells: astrocytes, Hortega's microglia cells and oligodendroglia.

The retina was cut on the flat, while the optic nerve was sectioned transversely and lengthwise. The staining methods were the following: Hortega's silver carbonate, Cajal's gold sublimate and a modification of Hortega's method by the author.

The author first describes the normal appearance of these three forms of glial cells in the retina and optic nerve. If the retina and optic nerve degenerate or atrophy, the astrocytes are the first to proliferate and hypertrophy in the affected areas and are the principal means of replacing tissue defects. While the oligodendroglia do not particularly hypertrophy in the optic nerve, they proliferate in retinal degeneration. This is a protective mechanism for the nerve elements against external injuries.

The oligodendroglia phagocyte foreign bodies in the retina. They occur in the optic nerve in the course of the nerve fibers and help in their nutrition. The Hortega cells react to pathologic stimuli, or to irritation in that they make order in diffuse hypertrophy. They do not take part in the glial hypertrophy present in degeneration of the retina and of the optic nerves. They act only as phagocytes.

Mueller's fibers proliferate as a result of pathologic irritation and take part in glial hypertrophy. They act in pathologic changes very similarly to astrocytes, so that the author is inclined to believe that they belong to astrocytes.

After experimental investigation, the glial tissue in the retina seems to proliferate in two ways: (1) secondarily, after atrophy of the nerve elements; (2) reactively to and preceding the degeneration. In the optic nerve the glial tissue proliferates secondarily to the destruction of the nerve elements.

A. KNAPP.

Bacteriology and Serology

THE SEDIMENTATION VELOCITY OF BLOOD CELLS IN EYE DISEASES CAUSED BY VITAMIN A DEFICIENCY. I. JOHN, Am. J. Ophth. **14:** 590 (July) 1931.

This is a contribution to the knowledge of systemic changes in the human body caused by vitamin A deficiency. Twenty-three adults were studied and the following conclusions made:

1. The blood sedimentation test was done in twenty-two patients with diseases due to vitamin A deficiency; seven of them suffered from keratomalacia and fifteen with xerotic changes in the eye of different degrees of severity, one patient having only hemeralopia.

2. Six of the patients with keratomalacia showed normal sedimentation figures.

3. Eight of the fifteen patients with xerosis also showed normal sedimentation figures.

4. The increased figures in seven cases of xerosis must be attributed to complications caused by other diseases, because the sedimentation figures, even after healing of the visible changes of the eye following

treatment with cod liver oil, showed also pathologically increased sedimentation velocity.

5. The sedimentation velocity in the cases with keratomalacia increased after starting treatment with vitamin A. W. S. REESE.

RELATIONSHIP OF IMMUNE BIOLOGIC REACTIONS TO HYPERSENSITIVITY TO LENS PROTEIN IN MAN AND ANIMALS. R. BRAUN, Arch. f. Augenh. **105:** 122, 1931.

The author first reviews the literature on the experimental production of precipitins to lens protein and discusses the question of organ specificity of the lens and the clinical question of endophthalmitis phacoanaphylactica. He then reports his own experimental work, which may be summarized as follows:

1. The injection of foreign lens protein into rabbits failed to produce precipitins, and the author therefore believed that lens protein was an excessively poor antigen.

2. He found, however, that by sensitization and later intoxication with foreign lens protein definite anaphylactic reactions could be produced in guinea-pigs.

He concludes: (1) that the production of precipitins is not possible either with foreign or with homologous lenses in rabbits and guinea-pigs, and (2) that the injection of foreign lenses will produce a hypersensitivity, and that allergic reactions can be evoked by a later shocking injection of such foreign lens protein. This, however, is not the case with homologous lens protein.

In the second portion of his paper he investigates the question of hypersensitivity to lens protein in man, and here uses the same general technic of intradermal injection which has been outlined by various American authors. The lens protein used in this case was swine lens protein, and as a control the author used horse serum. He found that 75 per cent of persons negative to the intracutaneous test with horse serum were likewise negative to the intracutaneous test with swine lens. On the other hand, 86.7 per cent of persons sensitive to horse serum were also sensitive to swine lens. He therefore concludes that the intracutaneous test with pig lens is too greatly influenced by nonspecific factors to permit its being of any clinical value.

The third portion of his investigations is concerned with the possibility of auto-iso-antibodies to lens protein in the serum of cataractous patients. Unable to demonstrate precipitins in the serums of such patients, he resorted to a passive sensitization experiment. In this experiment guinea-pigs were given intracardial injections of the patient's inactivated serum, and six minutes thereafter 0.5 cc. of the patient's lens by the same intracardial route. In the majority of such guinea-pigs, the author noticed a definite fall of temperature, which he thought suggested anaphylaxis due to the passive sensitization. He feels, however, that these experiments were inconclusive, but that they offered the only entity on which one could base the theory of endophthalmitis phacoanaphylactica.

These conclusions are so radically in conflict with those of other workers in this field that they will undoubtedly meet with prompt criticism. F. H. ADLER.

Cornea and Sclera

MARGINAL DEGENERATION OF THE CORNEA. L. LUGLI, Arch. di ottal. 38: 449 (July-Aug.) 1931.

The author reports three cases of marginal degeneration seen in a clinic in Bologna. In the first two there developed over a period of years a typical bilateral furrow around the corneal periphery, the corneas being thin in this area, and containing fine vessels that terminated centrally in a gray line of opacity. Periods of slight irritation and congestion marked the early stages in both cases, but no loss of epithelium was ever observed. Astigmatism developed which varied from 1.75 to 5 diopters. In one case vision was reduced to 6/10 in spite of correction in one eye, while in the other it could be corrected to about normal. One case occurred in a boy of 18, the other in a woman of 45, neither of whom showed general conditions that seemed to account for the condition. The blood cholesterol was 175 mg. per hundred cubic centimeters in one case, and 121 mg. in the other. The third patient, a woman of 43, showed, besides a furrow of the right cornea, a definite ectasia of the upper portion. The cornea was exceedingly thin at the summit of the ectasia and above it. A cystic cavity filled with clear fluid was present in the stroma. No signs of arcus senilis were present in either cornea. Vision in the right eye was reduced to 1/50 owing to corneal astigmatism of 20 diopters. The left cornea showed a slight thinning of its upper part near the limbus, containing thin vessels but with no fatty deposits in the cornea.

All of the cases showed endocrine disturbances: the first hypothyroidism, the second a premature menopause due to complete hysterectomy and the third premature senility. The author concludes that the glandular imbalance is the only factor that could be considered a cause in all cases. The deposit of fat, considered by Schieck to be the primary change, was absent in the third cases, while the relation to arcus senilis was absent in this case and in the first case in which the furrow began on the medial side. The author believes that the inflammatory symptoms, which were not present in all the eyes, were purely secondary. The cases are well illustrated by stereoscopic photographs. (Bibliography.)

S. R. GIFFORD.

THE HISTOLOGIC PICTURE OF GOLD DEPOSITS IN THE HUMAN CORNEA AFTER TATTOOING. L. SALLMANN, Arch. f. Ophth. 126: 297, 1931.

The author had the opportunity to enucleate a blind eye the cornea of which had been tattooed after the method of Knapp (2 per cent solution of gold chloride applied for four minutes) nine months previously. No irritation had followed the tattooing, but a few months later the eye became painful and slightly inflamed. Gold deposits were found in the middle and deep layers of the corneal stroma. Some of the deposits were dark red (probably colloidal gold). Descemet's membrane was heavily stained with gold, although glassy membranes do not store gold intra vitam if it is injected intravenously. This discrepancy will be dealt with in a later publication.

P. C. KRONFELD.

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P. C. KRONFELD.

Experimental Pathology

A New Type of Experimental Cataract: Isolated Posterior Polar Cortical Cataract in Albinotic Rabbits, Produced by Short-Wave Infra-Red Rays. A. Vogt, Klin. Monatsbl. f. Augenh. **86:** 289 (March) 1931.

Experiments made by the author between 1919 and 1924 proved that the eyes of albinotic rabbits require longer and more intense raying than those of pigmented rabbits. The pigment will store away the infra-red light to change it into convective heat, which favors the development of a cataract in these pigmented animals. Besides, the posterior area of the lens is more subject to opacification than the anterior, while the nucleus remains unaltered.

Vogt's specially constructed apparatus enabled him to produce isolated cataracts in a new series of albinotic rabbits. These cataracts resembled those produced by infra-red rays in the eyes of glass-blowers, blacksmiths and foundry workers. A translucent, white, posterior opacity appeared fifteen minutes, or less, after an exposure of from fifteen to sixty minutes through the pupillary center. Frequently a second opaque layer presented, leaving a transparent space between both of them, analogous to the glass-blower's cataract. The entire equatorial and peripheral posterior cortex was clear; the zonula in the area of artificial colobomas as well as the nucleus and the anterior cortex was intact, the iris and cornea unchanged.

Convective heat plays a small part, or none at all, in glass-blower's and foundry worker's cataract because of its prolonged and accumulative action. The resulting damage nevertheless is seen in the posterior, subcapsular cortex in both types, in the glass-blower's and in the experimentally produced, by a single, acute and very intensive exposure.

Exposures of from thirty to sixty minutes produced the same effect in pigmented and in albinotic rabbits, when the iris of the albinos was protected by a diaphragm. The fundus of the pigmented animal is subject to far greater damage by infra-red rays, than that of the albino.

Short-waved infra-red rays are more vividly absorbed by the lens than by the other refractive media of the eye. The intensity of absorption increases with age, when the nucleus suffers chiefly on account of the progressing sclerosis and diminished water contents. Yellow or red discoloration of the lens may have some influence. Convected heat may play a part in the development of the cataract of glass-blowers, etc., but the infra-red rays are predominantly responsible for their origin.

K. L. Stoll.

General Diseases

The Place of Ocular Tuberculosis in the General Tuberculosis Problem. W. Meisner, Ztschr. f. Augenh. **74:** 129 (May) 1931.

Tuberculous lesions of the eye may be primary or secondary in nature. When the eye is infected directly by the tubercle bacillus an ulcerated area is produced and the regional lymph nodes are involved. The conjunctiva is rarely the source of this type of infection. Usually the ocular tissue is invaded by the bacillus or its toxin through the blood stream. This lesion is the more common one and is usually bilateral.

The regional lymph glands are not, as a rule, involved in this disturbance. Frequently it is difficult in many instances to find the source of the tuberculous substance. It is well known that ocular tuberculosis is rarely observed in severe pulmonary tuberculosis. The author considers the recurrent vitreous hemorrhages in youth as a tuberculous disturbance. The lesion may heal without loss of vision or may terminate in retinal detachment or glaucoma. The uvea is frequently invaded by a solitary tubercle. The disturbance is usually monocular. Neither specific nor nonspecific therapy seems to influence the course of the disease. The process may be found in early life before immunity develops or may occur in adults after the general allergy against tuberculosis is diminished by way of some other concurrent constitutional disease.

Tuberculous panophthalmitis, metastatic tuberculous ophthalmia and conglobate tubercle seen in the choroid are probably due to a decreased allergic reaction in the body. The prognosis of the condition depends on the area involved and the allergic reaction of the patient. An addendum to this paper is made by Wardenberg of Davos, and it is devoted to the specific treatment of tuberculosis of the eye. It is very interesting and instructive.

A. M. YUDKIN.

Glaucoma

INDICATIONS FOR DIVERS OPERATIONS IN GLAUCOMA. T. AXENFELD, Klin. Monatsbl. f. Augenh. 85: 478 (Oct.) 1930.

Axenfeld discusses the medicinal and operative therapy of glaucoma. No abstract can do justice to this material which abounds in important detail of personal observations and the author's reasons for choosing divers methods. Although firm in his own views, Axenfeld always gave due credit to the opinions of others.

A contemplated operation for glaucoma should be preceded by the question: What can be accomplished with nonoperative therapy? Tonometric measurements should be taken at regular intervals for several days. A rise of the tension has frequently been found in the early morning. Correct application of the medicaments, drops during the day and ointment for the night, are essential and require for that end the training of a nurse or members of the family.

Timely operation, on the other hand, is required, even in chronic glaucoma. Epinephrine, as used by Wessely, Hamburger and others, ergotamine, ergotamine tartrate (gynergen brand), hormones and hypertonic salt solutions are adjuvants only.

The propaganda for conservative treatment must not cause the patient to fear the operation, or lead him to believe that an operation may be avoided. Undue postponement of operations may cause more harm to therapy in glaucoma than all the benefits derived by modern remedies amount to. It is equally wrong to tell a patient with glaucoma that an operation would never be required, as it is to believe that dietetic and general treatments of the body are sufficient to cure the glaucoma. Treatment of the vascular and nervous systems and of metabolism and blood pressure, also psychotherapy, however, remain valuable adjuvants to local ocular treatment. The eye is a "vascular province" in itself, influenced by every part of the body, but largely independent in its

change of fluids. Therefore it requires local treatment. Operations, nevertheless, still predominate in most cases. Iridectomy, since A. von Graefe's time, offers the most effective therapy in acute glaucoma and in glaucomatous attacks. Trephining is not superior to iridectomy in the latter. Some cases of simple glaucoma may even be benefited by iridectomy. Trephining by various methods has furnished good results; Axenfeld preferred that of Elliot. Peripheral iridectomy, although preserving the sphincter of the iris, "is not the best method always," because it may produce posterior synechiae, or it may be disturbing in patients with hemeralopia, or with progressive cataracts, or one just beginning. Trephining may be done in cases in which the simple glaucoma did not stop after iridectomy. A choice between trephining and cyclodialysis is generally unimportant. It is essential to remove thoroughly every trace of conjunctiva and elastic episcleral tissues from the site selected for trephining.

Hydrophthalmos presents especial difficulties. Anterior sclerotomy or cyclodialysis will be more effective and safe if a suture is laid through the superior rectus muscle. The operation should be performed early, and phenobarbital should be given according to the age of the child (see H. Meyer: *Klin. Monatsbl. f. Augenh.* **84:** 69 [Jan.] 1930; abstr. in ARCH. OPHTH. **4:** 243 [Aug.] 1930). In glaucoma with a luxated or subluxated lens, cyclodialysis may be performed, but trephining may be required later on. The indications for cyclodialysis and for posterior sclerotomy are considered in detail. The methods of examination are entered into.

K. L. STOLL.

Injuries

IMPREGNATION OF BOTH EYES WITH COPPER CAUSED BY BRASS SPLINTERS. PARTIAL DISAPPEARANCE OF THE CHALCOTIC CHANGES. H. K. MUELLER, Klin. Monatsbl. f. Augenh. **86:** 453 (April) 1931.

A boy, aged 8, exploded a dynamite cartridge with a hammer in 1925. His hands, chest and face were struck by particles, some of which entered both eyes. Impregnation of both lenses, corneas and retinas followed in the order mentioned, that of the lenses after fourteen months, of the corneas two months later and of the retinas after four years. Copper particles were found in the anterior capsule and adjoining stroma, while the posterior capsule showed a bluish hue with the slit-lamp. The chalcosis of the retina resembled the description given by Goldzieher in 1895. The impregnation was barely visible in the retinas eighteen months after its appearance, and the lenses were clear again. The copper particles in the corneas presented a ring-shaped arrangement, showing a larger breadth at the top and bottom of the ring. It had cleared almost entirely five and one-half years after the accident.

K. L. STOLL.

Instruments

COMPARATIVE STUDY OF THE OPHTHALMOTONOMETER. Y. SHOJI and S. SUZUKI, Acta Jap. Ophth. Soc., May, 1931, p. 29.

The authors compared the Schiötz, Bailliart and McLean instruments and found:

The average for normal eyes with the Bailliart instrument is 17.84 mm.; with the Schiötz instrument, 24.21 mm., and with the McLean instrument, 35.33 mm.

The most sensitive tonometer is that of McLean, then that of Bailliart and last that of Schiötz.

The highest reading in glaucomatous eyes over 50 or 60 mm. of mercury is recorded in the following order: Bailliart, Schiötz, McLean.

When ocular pressure is very low, all of the tonometers are unsuitable. The same holds true for cases in which there is excessively increased pressure.

As these three tonometers give different readings, it is always of importance in scientific communications to mention the kind of instrument employed.

A. KNAPP.

Lens

CLINICAL OBSERVATIONS ON SOEMMERING'S CRYSTALLINE SWELLING IN MYOPIC EYES OPERATED ON ACCORDING TO FUKALA'S METHOD: REPORT OF TWO CASES. F. Poos, Klin. Monatsbl. f. Augenh. **86:** 449 (April) 1931.

Twenty-five years ago, a man, now aged 47, had been operated on in both eyes for myopia according to Fukala's method. He had done his work without glasses until two years ago, when one eye had to be enucleated after an injury. Since that time he observed a cloud appearing in front of the other eye whenever he stooped over. A Soemmering's crystalline swelling was found, subluxated into the vitreous. The greater portion of this formation was hidden from view when the patient looked straight ahead, but it appeared in the pupil as soon as he bent forward. It was ring-shaped, the upper portion being slender, the lower bulky. Iridodonesis, deep anterior chamber, opacities of the vitreous and myopic changes in the fundus were observed, but the tension was normal. The vision was 6/12 with a minus three diopter lens; finest print could be read without a glass.

The second patient, a man, aged 40, had undergone the same operation as the first when 10 years old. Detachment of the retina in his left eye developed after a contusion which occurred in 1921. He suffered a contusion of his right eye in March, 1930, which caused a veil to appear in front of it, as soon as he stooped over. He succeeded in eliminating the veil temporarily by a certain jerk of his head. The symptoms mentioned in the first case were noticed in this case likewise, in addition to slight increase of the tension.

These two cases resemble one published by Wessely (*Arch f. Augenh.* **66:** 277, 1910), and two by A. Jess (*Klin. Monatsbl. f. Augenh.* **86:** 98, 1931). Luxation of Soemmering's crystalline swelling is caused by the weight of this formation, and by increasing myopia, coupled with progressing degeneration of vitreous and zonula, and an injury.

K. L. STOLL.

VARIOUS FORMS OF CONGENITAL CATARACT. TAWADO OGUCHI, Acta Jap. Ophth. Soc., May, 1931, p. 36.

The author has reported on the slit-lamp findings in various forms of congenital cataract.

1. Anterior axial embryonal cataract. This form was observed in about 22.6 per cent.

2. Anterior and posterior embryonal suture cataract. This form is not as frequent as the preceding, and differs from it by the fact that the suture itself is clouded. This opacity may affect the posterior as well as the anterior suture. Four cases of this cataract are described.

3. Dilacerated cataract. This has been described by Vogt as very unusual and involves the deeper layers of the adult nucleus and the axial zone. The author has been able to find three cases in which the cataract consisted of flat, irregular opacities with axes consisting of white dots and lines.

4. Coralliform cataract. This is a peculiar axial cataract described by several English observers, which appears in various layers of the lens. The "Spiess" cataract, observed by Vogt, and later by Gifford, probably belongs to this variety. The author has found a family in which this cataract was observed in three generations.

5. Central powdered cataract. This condition, first described by Vogt, has been observed by the author in two cases. The outline of the cataract is well defined. The dots are very fine and frequently run into one another.

6. Incomplete zonular cataract.

7. Two particular forms of central cataract.

A. KNAPP.

Neurology

THE PSEUDO-GRAEFE SIGN (FUCHS' SIGN). H. COPPEZ, Arch. d'opht. **48:** 385 (June) 1931.

The pseudo-Graefe sign consists of the elevation of the upper lid when the eye is turned downward. The author believes that it should be called Fuchs' sign, for not only did Fuchs first describe it, but it only slightly resembles Graefe's sign. He presents the report of a case in which this phenomenon occurred, well illustrated with photographs. Very few reports of the condition have appeared in the French literature, whereas in the German it is more frequent. The author discusses the probable mechanism of causation of this condition. He has had to discard his former idea of a fibrous adhesion in the orbit. Moreover, he points out that it is difficult to explain the condition entirely on the basis of a lesion in the nucleus of the third nerve. The spasticity of the muscles found in these cases resembles somewhat the secondary muscular contractures seen in hemiplegia.

S. B. MARLOW.

THE MECHANISM OF VESTIBULAR NYSTAGMUS: ON THE HOMONYMOUS UNCROSSED INNERVATION OF THE INTERNAL RECTUS FROM THE OCULOMOTOR NUCLEUS DURING NYSTAGMUS. BORIS KLOSSOWSKY AND A. M. LEVIKOWA, Arch. f. d. ges. Physiol. **228:** 199, 1931.

Since the investigations of Bernheimer it is known that the internal rectus muscle is supplied with both crossed and uncrossed fibers from the oculomotor nuclei. The present experiments were undertaken to determine whether the internal recti are innervated by both these fibers or by only one during horizontal nystagmus.

A description is given of the hypothetic pathways of the impulses from the labyrinth to the internal recti, and of the details of the operative approach to these fibers. The authors used cats throughout.

After section of one posterior longitudinal bundle in its course between the abducens and the trochlear nucleus, the horizontal nystagmus on the homolateral side became weaker. The nystagmus on the contralateral side did not change. If, now, the external recti muscles were dissected away together with the external insertions of the retractor bulbi muscle, the nystagmus ceased in the homolateral side and became weaker on the contralateral side.

From these results the authors draw the conclusion that during horizontal nystagmus the internal recti are innervated only by fibers from the homolateral oculomotor nucleus.

FRANCIS HEED ADLER.

CASE OF PARALYSIS OF THE SIXTH NERVE AFTER LUMBAR ANESTHESIA. KINNOSUKE HIROSE, Acta Jap. Ophth. Soc., September, 1931, p. 113.

The patient, aged 53, was operated on for hemorrhoids, lumbar anesthesia being used. After the operation there was moderate headache, and on the seventh day the patient complained of diplopia. On examination the eyes were normal, except that there was paresis of the left external rectus muscle. The condition was healed after forty days.

A. KNAPP.

Operations

IRIDECTOMY AB EXTERNO. B. CARRERAS, Arch. de oftal. hispano-am. 31: 369 (Sept.) 1931.

The difficulties and dangers arising from extreme narrowness of the anterior chamber in the performance of iridectomies in acute glaucoma and in similar conditions decided the author to make, in these cases, the scleral section from without inward, a procedure that he later extended to almost all of his iridectomies.

Although the author has employed this method since 1927, he did not publish anything on the subject, considering the procedure as a simple modification of the Foroni operation, but the recent publications of similar procedures by Elschnig and Salzmann induce him to do so at present.

After cocainization of the conjunctival sac and a retrobulbar injection of the region of the ciliary ganglion with a procaine hydrochloride and epinephrine solution, Carreras lifts and snips a vertical fold of the conjunctiva 8 mm. from the limbus. He then enlarges the opening parallel to the limbus until its length reaches 20 mm. He then raises the flap and everts it on the cornea. At a distance 1.5 mm. from the limbus, he cuts down with a sickle-shaped knife, layer by layer, on the sclera, the length of the incision being from 6 to 8 mm., until this is perforated. The wound is then carefully enlarged with scissors; iridectomy is performed; the pillars of the coloboma are reduced, and the flap is sutured down.

The advantages obtained are: avoidance of hemorrhage in cases of iridocyclitis and from a sudden reduction of intra-ocular pressure, no

injury to the iris during the making of the section, absence of danger of injury to the lens and better excision of the iris.

The author has also successfully employed this method in the extraction of foreign bodies from the iris angle.

The procedure was originally advocated by Gayet in 1884.

C. E. FINLAY.

Pharmacology

EXPERIMENTAL RESEARCHES ON THE INTRODUCTION OF NEOARSPHENAMINE INTO THE EYE BY MEANS OF IONIZATION. I. ABRAMOWICZ and F. GROSSMAN, Arch. d'opht. **48:** 443 (June) 1931.

This paper presents a series of experiments performed to ascertain the conditions favorable to the passage of arsenicals dropped into the conjunctival sac through the cornea into the anterior chamber by means of ionization. This study was stimulated by the knowledge that spirochetes have been demonstrated in the cornea in cases of interstitial keratitis by Igerheimer and others. The authors have succeeded in introducing arsenic into the aqueous of rabbits by their method. They hope to apply their experimental results clinically.

S. B. MARLOW.

Physiologic Optics

THE THEORY OF SPECTACLE AND MAGNIFYING GLASSES. M. SUNDQUIST, Arch. f. Ophth. **126:** 1, 1931.

This paper is a continuation of two previous publications (*Arch. f. Ophth.* **120:** 349, 1928; **121:** 639, 1928). The papers all deal with problems of physiologic optics and require for their understanding only a limited knowledge of higher mathematics (merely the principles of the application of differential calculus). With that knowledge it is easy to follow the author on his trip through the "labyrinth" of physiologic optics as it is still considered by the majority of ophthalmologists. He uses mainly the method of Abbé, but modifies it considerably for the special purposes of the ophthalmologist. The present paper (172 pages) deals with the errors in the image formation of regular spectacle lenses and magnifying devices. The author states that Gullstrand's papers on this subject are of little value for the eye practitioner, because he would have to work steadily for a whole year to acquire the mathematical skill necessary to "begin" studying Gullstrand's papers.

P. C. KRONFELD.

Physiology

FURTHER INVESTIGATIONS ON THE INFLUENCE OF STIMULATION OF THE SYMPATHETIC ON THE RETINA. S. KOGO, Arch. f. d. ges. Physiol. **227:** 727, 1931.

In previous work by Ducret and Kogo (*Arch. f. d. ges. Physiol.* **227:** 71, 1931) no change could be found in the retinas of frogs when the cervical sympathetic was cut on one side. Some of the frogs were adapted to the dark and others to the light before the experiment, but in no case could a distinct difference be found between the retinas on

the two sides. In view of the positive findings of other investigators who studied the effects of epinephrine, it was thought advisable to study the effects of electric stimulation of the sympathetic nerve on one side.

Frogs were adapted to the dark, and the cervical sympathetic in the region of the ansa subclavia was stimulated electrically for thirty seconds. A dilatation of the homolateral pupil was always observed, and usually a slight dilatation of the contralateral pupil also. The retinas of both eyes were examined histologically, and any changes in the position of the retinal pigment were carefully noted.

In spite of the fact that the frogs were adapted to the dark in the majority of cases, the pigment was found to occupy the position characteristic of the eye partially adapted to the light. This was true for both the side on which the operation had been performed and that on which it had not been performed, so that the authors were forced to the conclusion that the operative procedure itself was the determining factor. It was certain that stimulation of the sympathetic was not the cause.

No definite difference could be noted between the two sides. The conclusion is drawn, therefore, that if the sympathetic has any influence on the position of the pigment in the eye adapted to the dark, it is too minute to be detected.

FRANCIS HEED ADLER.

THE GRAPHIC PRESENTATION OF THE COURSE OF ADAPTATION. H. K. MUELLER, Arch. f. Ophth. **125:** 614, 1931.

After a critical discussion of the various ways of recording and presenting the course of adaptation, the author recommends to put down the time in arithmetical progression on the abscissa and the logarithms (with the base 10) of the light thresholds perceived on the ordinate axis. Every adaptometer has to be standardized by means of a photometer before the results obtained with it are comparable to those obtained by other investigators with different instruments.

P. C. KRONFELD.

Refraction and Accommodation

PRACTICAL EXPERIENCE CONCERNING THE CORRECTION OF REFRACTIVE ERRORS BY CONTACT GLASSES. C. H. SATTLER, Deutsche med. Wchnschr. **57:** 312 (Feb. 20) 1931.

The author recites the history of the contact glass. The differences and qualities of Muller's blown glass and the Zeiss polished glass are detailed. Types of suitable cases are cited. In using the Zeiss glass it is necessary, especially in cases with high degrees of astigmatism, to depend mainly on the ophthalmometer. At the first fitting no local anesthetic is used, as the patient is better able to tell if a correct fit is made. Most patients will wear the glass from eight to fifteen hours without discomfort. The longest time a glass was worn was twenty-six hours, but half an hour after the removal a cloudiness of the cornea was noted. The advantage of the contact glass over ordinary lenses is in the appearance, increase of vision, lessened prismatic effect and increase in the field of vision. Dispersion of colors is not present, and there is no clouding of the lens in coming from the cold into a warm room. It also protects the eyeball against trauma. The author reports only

two cases in which the cornea was affected by the long wearing of contact glasses. In both of these, one with the Müller type, the other a Zeiss, there was evidence of a preexisting corneal disease. There is reason to believe that increase of myopic astigmatism is stopped or even retarded by use of the contact glass, as shown by one of Heine's cases. With a reduction in the cost of the glass, its easily accomplished use by the patient would seem to offer great hopes to the author. A bibliography is appended.

L. L. MAYER.

Retina and Optic Nerve

DIABETIC RETINITIS IN A PATIENT AGED TWENTY-TWO. P. H. ADAMS, Brit. J. Ophth. **16:** 38 (Jan.) 1932.

The right eye of a man, aged 22, is the seat of inflammation, the pupil being filled by a grayish exudate. The superior temporal vein is somewhat engorged, and there are yellowish areas of retinitis at the macula and one mossy retinal hemorrhage. In the left eye there are no obvious signs of disease in the retinal blood vessels, though there are mossy and punctate hemorrhages.

The urine contained a very fair amount of sugar, a very faint trace of albumin and no acetone or diacetic acid. The blood sugar at 2:30 p. m. was 0.3 per cent, and the blood pressure was 100 systolic and 75 diastolic.

W. ZENTMAYER.

THE RESULTS OF OBLITERATING CAUTERY-PUNCTURE IN DETACHED RETINA. J. GONIN, Ann. d'ocul. **168:** 689 (Sept.) 1931.

The author says: "The present series of 300 observations has confirmed entirely what I have said for many years, that is, that a tear of the retina is the determining cause of the detachment called 'spontaneous,' and that obliteration of this opening suffices in recent cases to procure a complete and durable cure." Obliteration may be obtained by reapplication of the tear of the raised retina, either indirectly by the formation of adhesions between the ends of the retinal opening and choroid, or by a cicatrix which obstructs the progress of the detachment, in the presence of a large tear especially of a peripheral detachment of the retina.

In more than 50 of the total number of cases (65 of a total of 300 in my series), one thermopuncture directly on the tear suffices to cause obliteration and permits cure in about fifteen days. In patients operated on in the first three weeks, the proportion of successes is found to be doubled. In 53 of the 300 cases, we were obliged to repeat the thermopuncture because the first application was incomplete or was followed by a relapse. In detachments of less than one year, cures may be obtained in the neighborhood of 40 per cent, while cases dating over three months show in my experience about 48 per cent, and this can be brought to 55 per cent if the operative intervention is made at least three weeks after the appearance of the detachment.

All relapses indicate an insufficient obliteration of the initial tear, or the presence of another not reached by the cautery. A relapse due to

the production of a new tear independent of that which caused the first detachment may be met with after a few months or years, and even though it is a troublesome complication, the possibility of renewing treatment with subsequent cure is not excluded.

Of all procedures proposed up to the present, the application of the thermocautery directly to the retinal tear is the one that gives the most certain results. Operators who do not give sufficient attention to retinal tears expose themselves to the risk of numerous failures.

S. H. McKee.

Ophthalmoscopic Changes Observable at Arteriovenous Crossings in the Retina as Signs of Vascular Sclerosis. Alberto Urrets Zavalía and Ramon A. Brandan, Arch. de oftal. hispano-am. 31: 617 (Nov.) 1931.

After stressing the importance of the ophthalmoscopic examination of the retinal vessels, which is only possible with mydriasis and direct ophthalmoscopy, preferably with Gullstrand's large ophthalmoscope with Zeiss' binocular attachment, combined in some cases with red-free light from the Vogt lamp and Morton's ophthalmoscope, the author insists especially on taking note of the arteriovenous crossings. He quotes in this respect the publications of Adams, O'Hare, Walker, Pines, Barlow, Altnow, Agatson, Guist, Lijó Pavia and especially Salus, whose observations mostly coincide with his, notwithstanding certain differences and interpretations.

He next describes changes noticeable at different stages, of which he differentiates six, which he describes and explains in detail. He then relates these different changes to different general processes, especially to arteriosclerosis. Thus in subacute and subchronic glomerular nephritis where the fundi lesions, such as papilledema, retinal hemorrhages and white spots, are marked, the crossings are normal, indicating the absence of sclerotic lesions of the blood vessels; this negative showing permits the differentiation from chronic forms with similar clinical syndromes where the crossings are pathologic. In the severe kidney troubles of pregnancy, almost invariably accompanied by arterial hypertension, the examination of the condition of the retinal vessels, especially at the crossings, permit the drawing of more accurate conclusions as regards the diagnosis and prognosis of the case. In the pure nephritis exgraviditate and ingraviditate the crossings are normal, while when one has to deal with a chronic glomerular nephritis aggravated by pregnancy they are pathologic, the degree of the lesion allowing a determination of the stage of the process. In the second stage of chronic glomerulonephritis, without renal insufficiency, the lesions at the crossings present themselves early. In genuine hypertony the loss of transparency of the retinal arteries is an early symptom of the process. Finally, in arteriosclerosis, of no matter what origin, the process is evident at the crossing, especially in cerebral complexes, the condition of the retinal vessels allowing inferences as to that of the cerebral vessels.

C. E. Finlay.

THE LOCALIZATION OF RETINAL TEARS. M. C. COLENBRANDER, Arch. f. Ophth. **126:** 424, 1931.

The author recommends the hand perimeter of Schweigger combined with a reflecting ophthalmoscope for the determination of the two angles necessary for the localization of retinal tears, namely, the parallel circle (the eccentricity) and the meridian. For the measurement of the former, the perimeter can be brought in any desired position; thus the observer is enabled to see the extreme periphery of the fundus. For the determination of the meridian, it is necessary to start out from the primary position of the eye with the handle of the perimeter in the vertical position. To transpose the angles measured with this method into arcs or chords that can be traced out on the surface of the globe, the author has worked out a very accurate graphic method which considers the thickness of the sclera and the discrepancy in the position of the theoretical and the practical retina. For an average emmetropic eye the following relations were found:

Angle of incidence, degrees.....	90	80	70	60	50
Distance from limbus in millimeters:					
On the nasal side	8	10	12	14	16
On the temporal side	7	9	11	13	15

The author finally states that if the measurements taken with the hand perimeter are repeated until consistent results are obtained and the figures obtained by his graphic method are used, the same degree of accuracy can be accomplished as with the complicated apparatus of Guist or that of Weve.

P. C. KRONFELD.

THE QUESTION OF THE EXISTENCE OF A GENUINE EMBOLISM OF THE CENTRAL RETINAL ARTERY. R. HOFFMANN, Klin. Monatsbl. f. Augenh. **86:** 303 (March) 1931.

The predomination of acute blindness in ischemia of the retina is due to embolism of the central retinal artery, in Leber's opinion. Harms and Scheerer, on the other hand, assert that no case of actual embolism of the central retinal artery is known. Hoffmann accepts Leber's point of view, at least in cases that occur in young people. He bases his contention on the following case.

A man, aged 24, who had never been sick before, became suddenly blind in his left eye, with the clinical appearance of total embolism of the central retinal artery, four weeks after tonsillitis, complicated with pain in his joints and in the area of the heart. On the day after the attack of blindness he could see again with the upper portion of his field of vision. Partial embolism of the superior temporal branch was found on the fourth day, the embolism presenting itself in form of a cylindric particle of a yellowish-white hue. Although it had not obliterated the artery completely, the retinal portion peripheral to this body did not recover. The arteries, contracted at first by ischemic paralysis, regained their normal size a few days later. The macula was not involved. Arteriosclerosis, syphilis and endarteritis could be excluded. The dislocation of the embolus from the trunk of the central artery to the branch would explain the return of partial vision after initial total blindness.

Valvular heart disease was found in 55 per cent of cases of obstruction of the central retinal artery in all persons less than 45 years of age. Only in 17 per cent of those who received a general physical examination could no source of embolism be found. The author concludes that the absence of a valvular heart disease in the case mentioned proves the occurrence of embolism of the central retinal artery without this condition.

K. L. STOLL.

THE ETIOLOGY AND PROPHYLAXIS OF RETINITIS PIGMENTOSA. K. V. SUDAREFF, Russ. J. opht. **14:** 57 (July) 1931.

The author reports a case of retinitis pigmentosa which developed after typhus exanthematicus. He draws the attention to the similarity of the histologic changes in both diseases—the degeneration of the nervous elements and hyperproduction of pigment.

A review of the literaure on the etiologic factors causing retinitis pigmentosa is given. The author stresses the fact that hyperproduction of pigment is often in close relationship with the endocrine glands system. Since the etiology of retinitis pigmentosa is not definitely established, treatment should be directed in each case individually against the suspected cause. The prophylaxis should be aimed at the control of chronic and acute infectious diseases. The building up of the general health of the patients, which will make them more resistant to any trauma, and the inheritance factor should be looked after.

OLGA SITCHEVSKA.

CHANGES OF THE LENTICULOSTRIATE ARTERIES IN PATIENTS WITH NEPHRITIC RETINITIS. TADAOKI SUDZUKI, Acta Jap. Ophth. Soc., August, 1931, p. 108.

In two cases of contracted kidney, which were clinically examined, the author has investigated anatomically the lenticulostriate arteries, the parts of the brain that these arteries supply in the neighborhood of the internal capsule, the kidneys, heart and both eyeballs.

Arteriosclerotic changes and their consequences were general. There was a parallelism between the changes in the retina and in the cerebral tissue consisting in a thickening and a fatty hyaline degeneration of the smaller arteries, with perivascular destruction of tissue, small hemorrhages and foci of degeneration in the parenchyma of both tissues.

A. KNAPP.

Trachoma

FOREIGN TRAVELERS IN MARSEILLES AND TRACHOMA. H. VIOLLE, Rev. internat. du trachome **8:** 125 (July) 1931.

Up to the year 1927, all visitors to France were examined for trachoma on departure. Since then, an examination has been made both on entrance and departure. The records of cases of trachoma have fallen from 3.08 per cent of cases in 1926 to 0.64 per cent in 1930. The value is obvious. The author bemoans the fact that the procedure is not entirely medical.

L. L. MAYER.

THE DIFFICULTY IN DIAGNOSIS OF PAPILLARY TRACHOMA. MORAX AND JEANDELIZE, Rev. internat. du trachome **8:** 134 (July) 1931.

A case of papillary trachoma seen by the authors over a period of more than a year, the diagnosis of which was greatly delayed, is reported. The patient had a mild conjunctivitis of the right eye, slight secretion with some small bulbar hemorrhages. There was no preauricular gland enlargement but pain in this region. Bacteriologic examination gave negative results. The patient was from a region in which trachoma is rare. A week later there was little change. The pain persisted. A few follicles were noted appearing like those seen in follicular conjunctivitis or in swimming conjunctivitis. Treatment consisted of atropine and tannin. After a month the pain had disappeared. Morax found increased secretion, especially in the morning, a moderate narrowing of the palpebral fissure, and papillae on the conjunctiva of the superior tarsus and both superior and inferior culdesacs. The cornea was intact. He thought it was a swimming conjunctivitis, but the history contradicted this. A 1 per cent silver nitrate solution was prescribed. In the course of a year the patient was seen frequently, but showed little or no change. At about this time the left eye became affected in a similar way, but without pain. Epithelial scrapings of the left eye showed numerous inclusion bodies. It was now concluded that trachoma existed in both eyes. A grattage was done and treatment with copper sulphate instituted. The influence of this treatment was remarkable in clearing the condition in a very short time. During the entire course of the disease the corneas were not involved.

L. L. MAYER.

INTERSTITIAL KERATITIS AND TRACHOMA. J. SÉDAN, Rev. internat. du trachome **8:** 168 (July) 1931.

This is the resumption of an observation made in a previous report of the case of a patient with trachoma whose condition was greatly improved by the neoarsphenamine used for concomitant syphilis. When he was first observed, in 1918, with ulcer of the cornea and pannus, he was treated with little success for four years. In 1922, he had a chancre and received twelve injections of arsphenamine. During this period, in spite of negligible ocular therapy, amelioration of the trachoma was pronounced. The author does not believe that this was coincidental. Recently he has observed two cases of interstitial keratitis with trachoma. In one case the keratitic condition responded very slowly to antisyphilitic treatment, but the irritative symptoms of trachoma cleared markedly. After a year there were no lesions of trachoma. In the other interstitial case, the patient had received treatment of all kinds for his trachoma. Recent treatment for the interstitial keratitis had helped the trachoma, but it was too early in the course for the author to make a complete report. The author voices the opinion that the results obtained may be due to the known value of the arsenicals on micro-organisms and parasites. Cyanide or iodide of mercury has never given any satisfaction in trachoma. The author recalls the fact that de Waelle, in 1920, urged the use of arsenicals for trachoma.

L. L. MAYER.

Tumors

ANATOMICOPATHOLOGIC STUDY OF ORBITAL MELANOMAS. J. CASANOVAS, Arch. de oftal. hispano-am. **31**: 549 (Oct.) 1931.

After general considerations of melanomas, the different histogenetic theories advanced and the characteristics presented by melanomas in the different tissues of the eye, the author takes up primary melanomas of the orbit, stressing their rarity. Not more than twenty-five cases have been reported. He presents the case of a woman, aged 60, who had trachoma with marked corneal changes of one year's duration, with a prior history of traumatism in the affected eye three years previously. Exenteration of the orbital contents revealed a pigmented tumor posterior to the eyeball, surrounding the optic nerve. There was no recurrence after two and a half years.

At one spot a breach of continuity was observed in the sclera. The tumor consisted of different types of cells; the majority were round and medium-sized, and some were fusiform; there were great varieties in the dye affinities of the nuclei. Many of the cells contained fine yellowish granules; in others the granules were more diffused. In other spots the pigment formed more or less spherical masses with no systematic relations with the blood vessels. The tumor was not very vascular, but some hemorrhagic areas were observed. Although possibly some of the pigment was of hematic origin, it was evident that most of it issued from chromatophores, as was proved by hemosiderin reactions. A study of the conditions at the scleral breach led the author to conclude that the origin of the tumor was not choroidal and that the breach was not due to extension of the tumor but to an intrascleral development at this spot. The tumor around the optic nerve did not involve its dural sheath. An examination of the conjunctival spots showed that these were of hemorrhagic origin with an absence of melanin.

The author, notwithstanding some objections, seems to incline toward van Duyse's theory of ectopic orbital localizations of elements destined for the uvea and sclera, which, forming Cohnheim germs, ultimately develop into melanosarcomas with typical chromatophores.

C. E. FINLAY.

Uvea

MALARIAL IRIDOCYCLITIS. SANCHEZ MOSQUERA, Arch. de oftal. hispano-am. **31**: 400 (July) 1931.

The author reports a case of iridocyclitis in which etiologic investigations as regards syphilis and tuberculosis proved negative, in which an examination of the blood revealed schizonts and rosette formations and in which improvement was obtained with the use of quinine.

C. E. FINLAY.

Society Transactions

EDITED BY DR. JOHN HERBERT WAITE

ROYAL SOCIETY OF MEDICINE, LONDON, SECTION OF OPHTHALMOLOGY

H. DICKINSON, *Reporter*

Clinical Meeting, Dec. 11, 1931

ELMORE BREWERTON, F.R.C.S., *President, in the Chair*

CASE OF RETINAL DETACHMENT. SIR RICHARD CRUISE.

For this case of detachment up and out, with a fair-sized hole in the extreme periphery, Cruise used a Foster Moore pin. It was first put 1 mm. too far back. This was corrected, and there has been no detachment since. Vision has improved from perception of hand movements to 6/24.

CASE OF CHOROIDAL CARCINOMA. MR. O. GAYER MORGAN.

The patient, a woman of 36 years, had carcinoma of the breast, which was long neglected before it was treated with radium. Three months before presentation there was failure of vision in one eye. Examination now revealed a central detachment of the retina, containing new vessels on the surface. Mr. Morgan regarded the new growth in the eye as a metastasis from the breast. Removal of the eye was advised.

CASE OF RETINITIS PUNCTATA ALBESCENS. MR. COLE MARSHALL.

Nettleship, in connection with three cases reported in 1885, made the point that vision does not diminish in retinitis punctata albescens. The alarming thing about the present case was that since last February the vision had diminished from 6/12 to less than 6/60, and at the macula a fine retinitis was found. The patient had many decayed teeth. After these were extracted, vision improved. The exhibitor therefore thought that two conditions were present, retinitis punctata and a fine retinitis due to some septic condition.

CASE OF CORNEAL OPACITY. MR. JOSEPH.

The opacity progressed during six months from the limbus to the center of the cornea, but there was no pain or inflammation. The case was first seen on the previous day.

DISCUSSION

MR. ELMORE BREWERTON: Mr. Brewerton considered that a fungus was present, which had worked its way along Bowman's membrane. He advised scraping the opacity away by means of a small curet.

CASE OF EXCISION OF TARSAL PLATES IN TRACHOMA. MR. A. F. MACCALLAN.

This was a severe case of trachoma, stage 3 to 4, with a good deal of pannus and disability and very defective vision. The operation

carried out was the one devised by Sanders of the Royal London Ophthalmic Hospital. It is frequently performed in Egypt, and has given good results.

CASE OF A NEVOID CONDITION AND TELANGIECTASIS. MR. CARGILL.

The small telangiectases had been present since birth. The left eye was myopic, and did not give very good vision. A roentgenogram was going to be taken, and the eye watched for the development of glaucoma.

DISCUSSION

MR. ORMEROD: Mr. Ormerod thought that this case fell into the group that Ballantyne wrote about, i. e., nevoid conditions of the skin, associated with glaucoma or buphthalmos or sometimes with a defect in the visual fields. More work is required on these cases.

CASE OF SUPERFICIAL PUNCTATE KERATITIS. MR. FOSTER.

Seven weeks before presentation the eye became sore, and shortly afterward a punctate keratitis developed. The patient was sent to the hospital with the diagnosis of iridocyclitis, as the deeper changes were mistaken for precipitates. Examination with the slit-lamp proved them to be in the cornea.

CASE OF GLAUCOMA CAPSULOCUTICULARE. MR. CHARLES GOULDEN.

So far as Mr. Goulden knew, this was the first case of the condition published in this country. The patient, a woman, came to the hospital in July, 1929, complaining of a defect in the vision of the right eye. The tension was then normal. Later in the year she was found to have a posterior cortical cataract, and, by slit-lamp examination, a peculiar degeneration of the anterior capsule of the lens. Mr. Goulden saw her next two months before this meeting; she then had marked glaucoma in the right eye. An iridectomy was done. This condition is probably brought about by separation of the zonular lamella, particles of it becoming impacted in the spaces of Fontana. It is one of the causes of glaucoma in the anterior chamber.

CASE OF SEPARATION OF THE ZONULAR LAMELLA. MR. CHARLES GOULDEN.

The patient has been working at a grill as a chef for forty-seven years, and he considered that both eyes had been equally exposed to the heat of the fire. In the right eye there was a good deal of pale corneal precipitate, with endothelial bedewing. With the pupil dilated it could be seen that the zonular layer of the anterior lens capsule had become detached and protruded as a folded transparent membrane into the anterior chamber, almost touching the cornea. A good deal of uveal pigment was seen on the anterior lens capsule.

CASE OF ENDOTHELIAL DYSTROPHY OF THE CORNEA. MR. CHARLES GOULDEN.

This not very common condition was investigated by Mr. Basil Graves. The endothelium lost its configuration and presented the appearance of "beaten copper."

CASE OF DISCIFORM DEGENERATION OF THE MACULA. MR. SAVIN.

The patient was a man, aged 65, whose vision failed in the early part of the present year. He had syphilis in 1914, but the Wassermann reaction was now negative. He now had septic teeth, and they were under treatment. He also had emphysema, eczema of the groins and onychogryposis. The blood pressure was 165 systolic and 130 diastolic. The urine was normal. A circular area of edema was visible at the right macula, almost suggesting a detachment.

CASE OF RETINITIS PIGMENTOSA, DEGENERATION OF THE RETINA, NYSTAGMUS AND INTERNAL SQUINT. MR. SAVIN.

In addition to the ocular defects, this girl of 14 years had idiopathic dilatation of the colon (Hirschsprung's disease). Her brother had a similar ocular condition, but his colon was normal. The girl had not been able to pass a stool without an enema for six years. Usually cases of this kind end by perforation of the colon and death from peritonitis. Mr. Savin raised the question of some possible connection between Hirschsprung's disease and retinitis pigmentosa. The former is probably due to some lesion in Auerbach's plexus.

CASE OF CONGENITAL ABSENCE OF ALL FOUR PUNCTA. MR. SORSBY.

Both the patient's father and his grandfather had a similar condition. Probing had been unsuccessfully attempted.

CASE OF INJURY TO THE SUPERIOR OBLIQUE. MR. SORSBY.

The patient, a boy 20 years of age, noticed double vision after the blade of an open pen knife pierced his upper lid and orbit. The superficial wound healed in two or three days, but diplopia persisted for a month.

DISCUSSION

MR. F. J. CUNNINGHAM: Mr. Cunningham advised waiting a considerable time before doing anything, and cited a case that eventually cleared up without operation.

DR. E. E. MADDOX: Dr. Maddox said that he had had two or three cases of traumatic paralysis of the inferior oblique, treated successfully by recession of the superior rectus of the other eye. He had also had a case that was not traumatic.

Jan. 8, 1932

ELMORE BREWERTON, F.R.C.S., *President, in the Chair*

IMPLANTATION CYST FOLLOWING CATARACT EXTRACTION. MR. M. AFFLECK GREEVES.

The patient had been operated on for cataract in May, 1926. Discomfort and watering of the eye started three months prior to presenta-

tion. On examination, a cyst was discovered in the anterior chamber. The cyst was punctured, but refilled after a time.

DISCUSSION

MR. ELMORE BREWERTON: I recommend upward section, to include the prolapsed iris.

MR. J. H. FISHER: I suggest dissection level with the sclera, seizure of the wall of the cyst and withdrawal of it from the anterior chamber. In one of my cases I carried out a similar procedure. A sound scar resulted, vision returned to 6/6, and the eye has remained in good condition for fourteen years.

PANNUS OF CORNEA. MR. HUMPHRY NEAME.

Mr. Neame considered the case as one of trachoma, although it was not so regarded by a previous examiner. At the time of presentation, the palpebral conjunctiva was velvety and red, and there were irregular follicles, with pannus formation.

DISCUSSION

MR. MCCALLAN: The conjunctiva of both upper lids shows the effect of treatment, and I think that the upper lid is in the third stage of trachoma.

MR. FOSTER MOORE: When I saw the patient, she had a wash-leather-like protrusion over the cornea, which quickly disappeared of itself. The case has not run the course of trachoma, and I do not think that trachoma is the diagnosis now.

MR. J. H. FISHER: I agree with Mr. McCallan. I have not seen a case with such dense pannus as in this patient's left eye. This patient has the appearance of one with congenital syphilis. There are a loss of the nasal septum and a saddle-shaped bridge. I advise the younger members not to place absolute reliance on the result of the Wassermann test.

THE EYE OF SPHENODON, AND NOTES ON A LIVING SPECIMEN. MISS IDA C. MANN.

The Tuatera (Sphenodon punctatim) is the only extant representative of the order of reptiles. It occupies a position intermediate between tortoises and crocodiles on the one hand, and snakes and lizards on the other. It is now rapidly becoming extinct, and at the present time is found only in the islets off the coast of New Zealand.

The specimen of the species that Miss Mann examined had a total length of 44 cm. from the snout to the tip of the tail. The head was 8.5 cm. long, and the body, 17.5 cm. The skin had a grayish mud color, and was covered with small tubercles or scales. There were no external ears. The eyes were placed laterally, the angle between the optic axes being 160 or more. On top of the head was a raised spot of lighter color, making the site of the parietal eye. This became obscure or converted into a depression with age. This organ was covered with skin, and could be seen only after dissection.

The lateral eyes were provided with thick, movable lids, covered with greenish-brown scales. The palpebral aperture was 13 cm. from side to side, and when the eye was open, it was 4 mm. from above downward at its widest part. As the diameter of the cornea was 5 mm., it followed that the upper and lower corneoscleral junction was never seen exposed, and the iris was never seen completely. At the inner and outer canthus a triangular area of ocular conjunctiva was exposed. The pupil reacted well to direct illumination, changing from a circle to a vertical slit. There appeared to be no consensual reaction.

With regard to the appearance seen on focal illumination, the cornea was transparent and completely avascular. Practically no structure could be made out in it. The vessels stood up in high relief from a superficial layer of thin tissue of chocolate color, and this was more marked toward the pupil. No individual pigment cells were distinguishable, nor was the direction of the circulating blood, or its color, anywhere visible. All the vessels were of about the same caliber, and one could not distinguish between arteries, veins and capillaries.

On ophthalmoscopic examination, the fundus reflex was a pale silvery green. The optic disk was situated below and to the nasal side of the posterior pole. It was a kidney-shaped oval; its long axis was vertical, and its concavity was toward the temporal side. There was no pecten. Nerve fibers could easily be seen radiating from the disk; they had a silken sheen, more marked near the disk, gradually less visible peripherally. They were nonmedullated, and were much more easily seen than those of mammals. Their arrangement was almost exactly similar to that found in man. There were no vessels in the retina.

The specimen showed how early one can find evidence of specialization of the posterior pole, and how such an animal as the Sphenodon maintains its reputation as a "generalized reptile."

DISCUSSION

SIR JOHN PARSONS: The most striking feature of the Sphenodon is that it possesses a pineal eye. The development and functions of the macula in different species afford an interesting study in the psychology of perception.

SARCOMA OF THE CHOROID IN THE MACULAR AREA. MR. HUMPHRY NEAME.

The patient, a married woman, aged 50, was shown at a meeting of the Section in mid-November, 1931. She gave a history of micropsia and a slight disturbance of central color vision, which had been noticed two years previously. There was some evidence of the development of hypermetropic astigmatism in the place of myopia and myopic astigmatism in the left eye. In the left fundus oculi was an oval swelling in the macular area, projecting into the vitreous. The left eye was enucleated in November, 1931.

A spindle cell sarcoma of the choroid was found in the macula. The mass was 6 mm. horizontally and 5 mm. vertically. Bruch's membrane was ruptured, and was curled forward at its edge. No connective tissue stroma was seen within the growth, but it was composed of oval cells, with oval or circular nuclei, each containing a small, darkly stained nucleolus.

DISCUSSION

MR. HUGH THOMPSON: I saw the patient in March, 1931, at which time there was no suspicion of growth, and the fundus seemed to be normal. The patient reported that her vision had been deteriorating for a year. There was found, however, a distinct paracentral scotoma, down and in from the fixation point, about 30 degrees.

SIR JOHN PARSONS: I have always stressed the importance of retinal vessels as an indication of new growth. If a definite set of new vessels can be made out, one must consider neoplasm, and not cyst. Even a small sarcoma may be associated with simple detachment.

Feb. 12, 1932

ELMORE W. BREWERTON, F.R.C.S., *President, in the Chair*

PULSATING EXOPHTHALMOS. MR. EUGENE WOLFF.

A woman had noticed for seven months that her right eye was becoming more prominent. Some months before noting this, she bumped her head on the mantelpiece, and since then there had been a gradual diminution of vision, to the accompaniment of pain, especially over the second division of the fifth nerve. The right eye was much proptosed, and the proptosis was directly forward; the pulsation synchronized with the radial pulse. No bruit in the temporal fossa could be made out. With —2 glasses, vision in the right eye was 6/24. The right iris was of lighter color than the left, and the right pupil was sluggish and smaller than its fellow. In the fundus of the right eye there was dilatation of the retinal veins, with some haziness of the upper margin of the disk. No diseases of the nasal sinuses or hyperthyroidism seemed to be present, and the Wassermann reaction was negative. Mr. Wolff thought that the condition was a vascular growth.

DISCUSSION

MR. RANSOM PICKARD: Mr. Pickard said that the thrill elicited was a very fine vibratory one, the kind met with when there is a communication between two vessels, especially between an artery and a vein. He thought that a condition of this kind was present.

MR. FOSTER: Mr. Foster suggested that a tumor might have originated in the thyroid. In some cases the only manifestation is a secondary one, and often the thyroid is found to be implicated only when the autopsy is done.

CEREBRAL TUMOR. MR. A. F. MACCALLAN.

A woman fell on the back of her head in 1925, and ecchymosis of the lids followed. In 1931, she had a fainting fit. The fundi showed no pathologic change. Vision in the right eye was 6/18; in the left, 6/9.

The tonometer showed a tension of 30 in the right eye and of 35 in the left. The visual fields showed marked concentric contraction. The blind spots were much enlarged, and their size had increased a good deal in the last week. The Wassermann reaction was negative. Roentgenologically, the sella turcica seemed normal. The sugar metabolism was normal. Neurologic examination seemed to indicate a tumor in the pituitary region, as the optic chiasma was involved. The patient's weight had increased 20 pounds (9 Kg.) in nineteen days.

CONGENITAL NUCLEAR HYPOPLASIA. MR. O. GAYER MORGAN.

A boy, aged 11 years, had had bilateral facial paralysis and had been unable to move his eyes laterally since birth. In association he had other congenital malformations, including webbing of the fingers and talipes equinovarus. In infancy it was difficult to get him to suckle; there had been trouble with salivation, and epiphora had been present from the start. The boy was now very intelligent, and vision was good. His eyes now moved downward well, with slight convergence, but there was no lateral movement of either eye separately, or of the two eyes together.

DISCUSSION

MR. LESLIE PATON: Mr. Paton pointed out that the only way to secure any degree of convergence was by asking the boy to look at his own finger. These were very interesting cases, as it was difficult to associate the internal condition of the brain with the other facts.

PIGMENTED CYST IN THE RIGHT IRIS. MISS ROSA FORD.

A girl, aged 14 years, had a small swelling on the upper part of the right iris measuring from 2 to 3 mm. by 3 mm. The surface was irregular, with a little pigment on each side. The swelling overlapped the pupil, but did not reach the angle of the anterior chamber. When Miss Ford saw the condition a year before, she did not doubt that it was a cyst, but now it seemed to be more solid. There was no history of injury, not even slight trauma in infancy.

DISCUSSION

MR. T. HARRISON BUTLER: Mr. Butler spoke of an identical case of his own. The patient was 40 years of age, and had noticed the growth for two years. He had watched it for a year, and during that time there had not been any alteration in its size or consistency. It had been treated with radium at the Radium Institute, and it was now getting flatter and losing its defined outline. Both he and the staff of the institute thought that the growth was getting smaller. There seemed little doubt that it was endothelioma, but as it was not growing, he did not feel inclined to do anything. Recently this patient had the feeling of a marble in her throat; that might mean a secondary growth in the esophagus. He recommended radium for the present case.

MR. M. S. MAYOU: Mr. Mayou spoke of two cases that he had had of pigmented tumor of the iris. One was that of a man with a pigmented nevus, whom he saw for the first time fifteen years before. A drawing was made of the nevus at that time. Fifteen years afterward

the patient was seen again, and the tension had then begun to increase; occasionally the vision was misty. The tension seemed to show the onset of malignancy, and the eye was removed. A malignant growth spreading back into the ciliary body was found. Increased tension is very significant.

DISLOCATED LENS, PRESENT IN THE ANTERIOR CHAMBER FOR TWO YEARS. MISS ROSA FORD.

A woman, aged 77, was seen ten years before, when she had cataract in the right eye. The eye had been nearly blind since fourteen years previously. Four years before presentation the patient had an attack of iritis, and after that the lens was partially absorbed, so that she could see large objects. Recurrent iritis persisted for the next two years, with much pain. Just before the lens slipped into the anterior chamber the pain was almost intolerable, but immediately afterward it was much less; since then the eye had given little trouble. Projection was very poor. The patient declined treatment.

SECONDARY CARCINOMA OF THE ORBIT. MRS. MARTIN.

A woman, aged 66, had her left breast removed in 1929, and until four months before presentation she remained free from recurrence. Then she returned to the hospital with the complaint of bilateral mistiness of vision. There was early cupping in both eyes, and increased tension in the left, with relatively large pupils. Later there was loss of the whole of the nasal field of vision, and complete ophthalmoplegia, with ptosis and slight proptosis of the left eye. Still later she had optic atrophy and no perception of light. A small lump appeared in the upper and inner angle of the left orbit. The frontal sinus was clear. She had received eleven exposures of deep x-rays, but with little improvement.

HEMANGIOMA OF THE RETINA (ANGIOMATOSIS LINDAU). MR. HEATH.

For eight months a woman, aged 23, had been unable to seen anything with the left eye when vision was directed straight ahead. The right eye was normal, with 6/6 vision. The reactions in the left pupil were more sluggish than those in its fellow, and the left fundus showed a detachment.

DISCUSSION

MR. TREACHER COLLINS: Mr. Collins said that this condition was often associated with cerebellar disease, and as it was sometimes familial, a watch should be kept on all members of the family. As such cases always ended in blindness, there could be no harm, and might be some good, in passing an electrolytic needle into the mass.

MR. LESLIE PATON: Mr. Paton referred particularly to the beading of the artery. Also in some cases of this kind the associated cranial disease was cerebral, not cerebellar.

EXFOLIATION OF THE IRIS STROMA. MR. F. JULER.

One could see the sphincter muscle standing out naked, as a light brown object on a dark brown area. There was no history of trauma

in the case. It was doubtful whether this was altogether a congenital anomaly: it was probably atrophy superimposed on a congenital condition.

DIFFERENTIAL DIAGNOSIS OF CERTAIN WHITE DEPOSITS SEEN IN THE FUNDUS. MR. MALCOLM L. HEPBURN.

The author had noted a recent tendency at the meetings to describe cases of white or yellowish-white deposits in the fundus as either exudative retinitis or Coats' disease, though they had little claim to be so regarded. He hoped by this paper to pave the way to some agreed opinion. The title of the paper was so chosen as to exclude cases of white patches and deposits about which there was no difference of opinion or difficulty of diagnosis, i. e., cases of metastatic inflammatory deposits or of fibrous tissue development, either at the macula or on the retina. The term "exudative retinitis" implied an inflammation of the retina with an exudation of albuminous or hemorrhagic fluid into the layers of the retina, a condition seen only in cases of retinitis due to renal disease, diabetes and diseases of the retinal vessels. It was not surprising that the exudates in retinitis showed a tendency to encircle the macula. Since their origin was the retinal vessels, their tendency was to accumulate in the vicinity of the larger vessels which surrounded the macula.

Mr. Hepburn reminded the members of the eight clinical and five pathologic points that Coats brought out in his original paper in 1908, which was entitled "Disease of the Retina with Massive Exudate," and said it was only by taking into consideration the accompanying clinical signs and symptoms and then watching, often for a long time, the ophthalmoscopic changes and subsequent behavior of these exudates that definite conclusions could be arrived at as to their cause. As the white deposits were widespread, often multiple and illdefined, he would hesitate to describe a single exudate, with a well defined border, occurring at the macula as an example of Coats' disease, however similar the ophthalmoscopic appearance. The most convincing proof was the pathologic and histologic one, but as opportunity for this was often lacking, one had to rely on the clinical evidence.

Mr. Hepburn then passed in review the literature that had appeared on the subject.

In the *Transactions of the Ophthalmological Society of the United Kingdom* (**48:** 150, 1928), Mr. Mayou reported the pathologic details in a case of widespread exudate with a retinal detachment. He found that the posterior layers of the retina were adherent to the choroid, the venae vorticosae were thrombosed, and the detachment had occurred between the anterior and posterior layers of the retina. He thus proved that the source of the hemorrhage was the choroid.

The type of white deposits that Mr. Hepburn discussed in this paper were those which occurred in the macular region and occupied practically the whole of that area. They often had a well defined border and were raised above the level of the rest of the fundus, while the retinal vessels showed no visible change in any part of their course and the disk was normal. There were three varieties of this kind of deposit: a new growth, simple serous exudations and extravasations of blood; at certain stages, these often looked much alike.

The usual aids to the diagnosis of a new growth were the occurrence of a small swelling at an early stage, which gradually increased in size while the patient was under observation; at a later stage new vessels coursed over the swelling, and a detachment of the retina might be discovered at a varying distance from the tumor. Sometimes there were deposits of pigment in the vicinity. On the other hand, the simple serous exudates and extravasations of blood occurred suddenly, attained their maximum size in the early stages and then, while under observation, slowly subsided, later undergoing various changes. These last two varieties gave rise to the greatest divergence of opinion, as the changes wrought so much alteration in the ophthalmoscopic appearance. Mr. Hepburn thought that it would be generally agreed that vascular changes of some kind were responsible for the white exudates at the macula.

Directory of Ophthalmologic Societies *

FOREIGN

British Medical Association, Section on Ophthalmology

President: Sir J. Herbert Parsons, 54 Queen Anne St., Cavendish Square, London, W. I.
Place: London. Time: July 27-29, 1932.

Ophthalmological Society of the United Kingdom

President: Mr. A. H. H. Sinclair, 6 Charlotte Square, Edinburgh.
Secretary: Mr. Humphrey Neame, 56 Portland Place, London, W. I.
Place: Edinburgh. Time: May 12-14, 1932.

Oxford Ophthalmological Congress

Master: Dr. Cyril Walker, Bristol, England.
Secretary: Dr. C. G. Russ-Wood, 12 St. John's Hill, Shrewsbury, England.
Place: Oxford. Time: July 7-9, 1932.

Société Française d'Ophthalmologie

Secretary: Dr. René Onfray, 6 avenue de la Motte Picquet, Paris 7è.
Place: Paris. Time: July 17-21, 1932.

German Ophthalmological Society

Secretary: Prof. A. Wagenmann, Heidelberg.
Place: Leipzig. Time: May 19-21, 1932.

International Ophthalmologic Congress

Secretary: Dr. E. Marx, Rotterdam, Holland.
Place: Madrid, Spain. Time: 1933.

NATIONAL

American Medical Association, Section on Ophthalmology

Chairman: Dr. Harry Friedenwald, 1212 Eutaw Pl., Baltimore.
Secretary: Dr. Parker Heath, 1551 Woodward Ave., Detroit.
Place: New Orleans. Time: May 11-13, 1932.

American Academy of Ophthalmology and Oto-Laryngology

President: Dr. S. Hanford McKee, 1528 Crescent St., Montreal, Canada.
President-Elect: Dr. B. R. Shurley, 62 W. Adams Ave., Detroit.
Executive Secretary: Dr. William P. Wherry, Medical Arts Bldg., Omaha.
Place: Montreal, Canada. Time: September 19-23, 1932.

American Ophthalmological Society

President: Dr. Edward C. Ellett, 130 Madison Ave., Memphis, Tenn.
Secretary: Dr. Emory Hill, Professional Bldg., Richmond, Va.
Place: New London, Conn. Time: June 27-29, 1932.

SECTIONAL

New England Ophthalmological Society

President: Dr. David W. Wells, Hotel Westminster, Boston.
Secretary-Treasurer: Dr. Theodore L. Terry, 243 Charles St., Boston.
Place: Massachusetts Eye and Ear Infirmary, 243 Charles St., Boston. Time: 8 p. m., third Tuesday of each month from November to April, inclusive.

* Secretaries of societies are requested to furnish the information necessary to make this list complete and to keep it up to date.

PACIFIC COAST OTO-OPHTHALMOLOGICAL SOCIETY

President: Dr. W. F. Hoffman, 317 Summit Ave., Seattle.
Secretary-Treasurer: Dr. Frank Friesen, 1208 Roosevelt Bldg., Los Angeles.
Place: Seattle. Time: June 30-July 2, 1932.

PUGET SOUND ACADEMY OF OPHTHALMOLOGY AND OTO-LARYNGOLOGY

President: Dr. John H. Harter, 1215 Fourth Ave., Seattle.
Secretary-Treasurer: Dr. Francis A. Brugman, 806 Cobb Bldg., Seattle.
Time: 8 p. m., third Tuesday of each month, except July and August.

SIOUX VALLEY EYE AND EAR ACADEMY

President: Dr. John B. Gregg, 101 S. Main St., Sioux Falls, S. Dakota.
Secretary-Treasurer: Dr. F. H. Roost, 420 Trimble Bldg., Sioux City, Iowa.
Place: Sioux City, Iowa. Time: November, 1932.

SOUTHERN MEDICAL ASSOCIATION, SECTION ON EYE, EAR, NOSE AND THROAT

Chairman: Dr. Wiley R. Buffington, 211 Camp St., New Orleans.
Secretary: Dr. William D. Gill, 323 Medical Arts Bldg., San Antonio, Texas.
Place: Birmingham, Ala. Time: November, 1932.

SOUTHWESTERN MICHIGAN TRIOLOGICAL SOCIETY

President: Dr. W. E. McGarvey, 802 Jackson City Bank Bldg., Jackson.
Secretary: Dr. Don C. Lyons, 1405 Union and Peoples National Bank Bldg., Jackson.
Time: Third Thursday of alternate months.

STATE

COLORADO OPHTHALMOLOGICAL SOCIETY

President: A presiding officer is selected for each meeting alternatelv until all members have served.
Secretary: Dr. Ralph W. Danielson, 258 Metropolitan Bldg., Denver.
Place: Capitol Life Building, Denver. Time: 7:30 p. m., third Saturday of the month, October to April, inclusive.

CONNECTICUT STATE MEDICAL SOCIETY, SECTION ON EYE, EAR, NOSE AND THROAT

President: Dr. M. H. Merriman, 115 Prospect St., Waterbury.
Secretary-Treasurer: Dr. Walter L. Hogan, 750 Main St., Hartford.
Time: May, November.

EYE, EAR, NOSE AND THROAT CLUB OF GEORGIA

President: Dr. W. L. McDougall, 50 Whitehall St., S. W., Atlanta.
Secretary-Treasurer: Dr. W. O. Martin, Jr., 412 Medical Arts Bldg., Atlanta.

INDIANA ACADEMY OF OPHTHALMOLOGY AND OTO-LARYNGOLOGY

President Dr. J. R. Gillum, 221 S. Sixth St., Terre Haute.
Secretary: Dr. J. Kent Leasure, 23 E. Ohio St., Indianapolis.

IOWA ACADEMY OF OPHTHALMOLOGY AND OTO-LARYNGOLOGY

President: Dr. Royal French, 28 S. First Ave., Marshalltown.
Secretary-Treasurer: Dr. W. F. Boiler, 105 E. Iowa Ave., Iowa City.

MICHIGAN STATE MEDICAL SOCIETY, SECTION OF OPHTHALMOLOGY AND OTOLARYNGOLOGY

Chairman: Dr. Wilfred Haughey, 303 Post Bldg., Battle Creek.
Secretary: Dr. H. O. Westervelt, 239 Pipestone St., Benton Harbor.

MINNESOTA ACADEMY OF OPHTHALMOLOGY AND OTO-LARYNGOLOGY

President: Dr. Douglas F. Wood, 74 S. Ninth St., Minneapolis.
Secretary-Treasurer: Dr. Walter E. Camp, Medical Arts Bldg., Minneapolis.
Time: Second Friday of each month from October to May.

MONTANA ACADEMY OF OTO-OPHTHALMOLOGY

President: Dr. L. H. Huber, Livingston.
Secretary: Dr. A. W. Morse, Phoenix Bldg., Butte.

NEW JERSEY STATE MEDICAL SOCIETY, SECTION ON OPHTHALMOLOGY, OTOLOGY AND RHINOLARYNGOLOGY

Chairman: Dr. H. L. Harley, 101 S. Indiana Ave., Atlantic City.
Secretary: Dr. B. E. Failing, 31 Lincoln Park, Newark.
Place: Atlantic City. Time: June 15-17, 1932.

NEW YORK STATE MEDICAL SOCIETY, EYE, EAR, NOSE AND THROAT SECTION

Chairman: Dr. R. T. Atkins, 4 W. Fifty-Third St., New York.
Secretary: Dr. D. F. Gillette, 109 S. Warren St., Syracuse.
Place: Buffalo. Time: May 23-24, 1932.

NORTH DAKOTA ACADEMY OF OPHTHALMOLOGY AND OTO-LARYNGOLOGY

President: Dr. F. L. Wicks, Valley City.
Secretary-Treasurer: Dr. W. L. Diven, National Bank Bldg., Bismarck.

OREGON ACADEMY OF OPHTHALMOLOGY AND OTO-LARYNGOLOGY

President: Dr. H. M. Hendershott, 193 Eleventh St., Portland.
Secretary-Treasurer: Dr. Andrew J. Browning, 418 Mayer Bldg., Portland.
Place: Good Samaritan Hospital. Time: Third Tuesday of each month.

RHODE ISLAND OPHTHALMOLOGICAL AND OTOLOGICAL SOCIETY

President: Dr. Frank W. Dimmitt, 195 Thayer St., Providence.
Secretary: Dr. N. A. Bolotow, 108 Waterman St., Providence.
Place: Rhode Island Medical Library. Time: 8:30 p. m., second Thursday in October, December, February and April.

SOUTH CAROLINA MEDICAL ASSOCIATION, SECTION ON OPHTHALMOLOGY AND OTOLARYNGOLOGY

President: Dr. W. B. McWhorter, 106 E. Earle St., Anderson.
Secretary-Treasurer: Dr. G. M. Truluck, Orangeburg.
Time: April and December.

TEXAS OPHTHALMOLOGICAL AND OTO-LARYNGOLOGICAL SOCIETY

President: Dr. W. D. Jones, 3116 Live Oak St., Dallas, Texas.
Secretary: Dr. A. F. Clark, 1034 Nix Professional Bldg., San Antonio.

UTAH OPHTHALMOLOGICAL SOCIETY

President: Dr. D. W. Henderson, 75 S. Main St., Salt Lake City.
Secretary-Treasurer: Dr. T. F. Welch, 14 Exchange Pl., Salt Lake City.

VIRGINIA SOCIETY OF OTO-LARYNGOLOGY AND OPHTHALMOLOGY

President: Dr. C. P. Jones, Newport News.
Secretary-Treasurer: Dr. H. G. Preston, 307 Professional Bldg., Harrisonburg.

WEST VIRGINIA STATE MEDICAL ASSOCIATION, EYE, EAR, NOSE AND THROAT SECTION

President: Dr. G. A. Smith, Montgomery.
Secretary: Dr. O. H. Bobbitt, Medical Arts Bldg., Charleston.

LOCAL

ACADEMY OF MEDICINE OF NORTHERN NEW JERSEY, SECTION ON EYE, EAR, NOSE AND THROAT

Chairman: Dr. Charles W. Buvinger, 50 Washington St., East Orange.
Secretary: Dr. Earl LeRoy Wood, 192 Roseville Ave., Newark.
Place: 91 Lincoln Park South. Time: 8:45 p. m., second Monday of each month.

ACADEMY OF MEDICINE OF TORONTO, SECTION OF OPHTHALMOLOGY

Chairman: Dr. P. J. F. Houston, 34 Hurndale Ave., Toronto.
Secretary: Dr. Alexander E. MacDonald, 151 Bloor St., W., Toronto.
Time: First Monday of winter months.

ATLANTA ACADEMY OF OPHTHALMOLOGY AND OTO-LARYNGOLOGY

President: Dr. John R. Childs, 45 Edgewood Ave., Atlanta, Ga.
Secretary: Dr. William O. Martin, Jr., Medical Arts Bldg., Atlanta, Ga.
Place: Academy of Medicine, 38 Prescott St., N. E. Time: 8 p. m., last Thursday of each month.

BALTIMORE MEDICAL SOCIETY, SECTION ON OPHTHALMOLOGY

Chairman: Dr. Alan C. Woods, 906 Cathedral St., Baltimore.
Secretary: Dr. Henry F. Graff, 513 N. Charles St., Baltimore.
Place: Medical and Chirurgical Faculty, 1211 Cathedral St. Time: 8:30 p. m., fourth Thursday of each month from October to May.

BROOKLYN OPHTHALMOLOGICAL SOCIETY

President: Dr. John N. Evans, 23 Schermerhorn St., Brooklyn.
Secretary: Dr. Michael J. Buonaguro, 589 Lorimer St., Brooklyn.
Place: Kings County Medical Society Bldg., 1313 Bedford Ave. Time: Third Thursday in February, April, May, October and December.

BUFFALO OPHTHALMOLOGIC CLUB

President: Dr. Joseph C. O'Gorman, 1324 Jefferson Ave., Buffalo.
Secretary-Treasurer: Dr. Thurber Le-Win, 112 Linwood Ave., Buffalo.

CHICAGO OPHTHALMOLOGICAL SOCIETY

President: Dr. Frank Brawley, 30 N. Michigan Ave., Chicago.
Secretary: Dr. Richard C. Gamble, 30 N. Michigan Ave., Chicago.
Place: Medical and Dental Arts Club. Time: Third Monday of each month from October to May.

CLEVELAND ACADEMY OF MEDICINE, SECTION OF OPHTHALMOLOGY AND OTO-LARYNGOLOGY

Chairman: DR. M. W. Jacoby, 2323 Prospect Ave., Cleveland.
Secretary: Dr. H. C. Rosenberger, 1065 Rose Bldg., Cleveland.
Place: Winton Hotel. Time: Fourth Friday of each month.

CLEVELAND OPHTHALMOLOGICAL CLUB

Chairman: Dr. Roy B. Metz, Hanna Bldg., Cleveland.
Secretary: Dr. Paul G. Moore, Medical Arts Bldg., Cleveland.

COLLEGE OF PHYSICIANS, PHILADELPHIA, SECTION ON OPHTHALMOLOGY

Chairman: Dr. L. F. Appleman, 308 S. Sixteenth St., Philadelphia.
Clerk: Dr. Alexander G. Fewell, 1924 Pine St., Philadelphia.
Time: Third Thursday of every month from October to April, inclusive.

COLUMBUS OPHTHALMOLOGICAL AND OTO-LARYNGOLOGICAL SOCIETY

Chairman: Dr. Ivor Clark, 188 E. State St., Columbus, Ohio.
Secretary-Treasurer: Dr. Francis W. Thomas, 327 E. State St., Columbus, Ohio.
Time: First Monday of each month.

DALLAS ACADEMY OF OPHTHALMOLOGY AND OTO-LARYNGOLOGY

President: Dr. L. M. Sellers, 717 Pacific Ave., Dallas, Texas.
Executive Secretary: Dr. W. Mood Knowles, 717 Pacific Ave., Dallas, Texas.
Place: Dallas Athletic Club. Time: 6:30 p. m., first Tuesday of each month from October to June. The November, January and March meetings are devoted to clinical work.

Des Moines Academy of Ophthalmology and Otolaryngology

President: Dr. Cecil C. Jones, 1121 Equitable Bldg., Des Moines, Iowa.
Secretary-Treasurer: Dr. Grace Doane, 614 Bankers Trust Bldg., Des Moines, Iowa.
Time: 7:45 p. m., third Monday of every month, September to May.

Detroit Ophthalmological Club

Chairman: Members rotate alphabetically.
Secretary: Dr. Raymond S. Goux, David Whitney Bldg., Detroit.
Time: 6:30 p. m., first Wednesday of each month.

Eastern New York Eye, Ear, Nose and Throat Association

President: Dr. F. M. Sulzman, 1831 Fifth Ave., Troy.
Secretary-Treasurer: Dr. Arthur F. Holding, 142 Washington Ave., Albany.
Time: Third Wednesday in October, November, March, April, May and June.

Fort Worth Eye, Ear, Nose and Throat Society

President: Dr. R. H. Needham, 1304 Medical Arts Bldg., Fort Worth, Texas.
Secretary-Treasurer: Dr. Van D. Rathgeber, 1011 Medical Arts Bldg., Fort Worth.
Place: University Club. Time: 6:30 p. m., first Friday of each month except July and August.

Grand Rapids Eye, Ear, Nose and Throat Society

President: Dr. Carl F. Snapp, 26 Sheldon Ave., Grand Rapids, Mich.
Secretary-Treasurer: Dr. Walter W. Oliver, 26 Sheldon Ave., Grand Rapids, Mich.
Place: Various local hospitals. Time: Third Thursday of alternating months, September to May.

Houston Academy of Medicine, Eye, Ear, Nose and Throat Section

President: Dr. L. W. Raney, 609 Fannin St., Houston, Texas.
Secretary: Dr. J. F. Gamble, 201 Main St., Houston, Texas.
Place: Medical Arts Bldg., Harris County Medical Society Rooms. Time: 8 p. m., first Thursday of each month from September to June.

Indianapolis Ophthalmological and Oto-Laryngological Society

President: Dr. B. J. Larkin, 23 E. Ohio St., Indianapolis.
Secretary: Dr. Kenneth L. Craft, Hume-Mansur Bldg., Indianapolis.
Place: University Club. Time: 6:30 p. m., second Thursday of each month from October to May.

Kansas City Society of Ophthalmology and Oto-Laryngology

President: Dr. W. E. Keith, 1103 Grand Ave., Kansas City, Mo.
Secretary: Dr. O. S. Gilliland, Professional Bldg., Kansas City, Mo.
Time: Third Thursday of each month from September to May. The November, January and March meetings are devoted to clinical work.

Long Beach Eye, Ear, Nose and Throat Society

President: Dr. R. R. Montgomery, 102 Pine Ave., Long Beach, Calif.
Secretary-Treasurer: Dr. Russell T. Uhls, 823 Security Bldg., Long Beach, Calif.
Place: Pacific Coast Club. Time: Last Wednesday of each month from September to June.

Los Angeles County Medical Society, Section on Ophthalmology and Oto-Laryngology

President: Dr. J. Frank Friesen, 1208 Roosevelt Bldg., Los Angeles.
Secretary-Treasurer: Dr. F. H. Brandt, 1052 W. Sixth St., Los Angeles.
Place: Mary Louise Cafe. Time: 6:30 p. m., fourth Monday of each month from October to May, inclusive.

Medical Society of the District of Columbia, Section of Ophthalmology and Oto-Laryngology

Chairman: Dr. James A. Flynn, 1511 Rhode Island Ave., Washington.
Secretary: Dr. E. R. Gookin, Medical Science Bldg., Washington.
Place: 1718 M St., N. W. Time: 8 p. m., third Friday of each month.

Memphis Society of Ophthalmology and Oto-Laryngology

Chairman: Each member, in alphabetical order.
Secretary: Dr. R. O. Rychener, Exchange Bldg., Memphis, Tenn.
Place: Eye Clinic of Memphis Eye, Ear, Nose and Throat Hospital. Time: 8 p. m., second Tuesday of each month. Annual meeting, Jan. 10, 1933.

Milwaukee Oto-Ophthalmic Society

President: Dr. T. F. McCormick, 324 Wisconsin Ave., Milwaukee.
Secretary-Treasurer: Dr. O. P. Schoofs, 324 E. Wisconsin Ave., Milwaukee.
Place: University Club. Time: 6:30 p. m., third Tuesday of each month.

Nashville Academy of Ophthalmology and Otolaryngology

Chairman: Dr. Hilliard Wood, 700 Church St., Nashville, Tenn.
Secretary-Treasurer: Dr. H. C. Smith, Medical Arts Bldg., Nashville, Tenn.
Place: St. Thomas Hospital. Time: 8 p. m., third Monday of each month.

New Orleans Ophthalmological and Otolaryngological Society

President: Dr. Charles A. Bahn, 150 Baronne St., New Orleans.
Secretary-Treasurer: Dr. M. F. Meyer, Canal Bank Bldg., New Orleans.
Place: Eye, Ear, Nose and Throat Hospital. Time: Third Thursday of each month from October to June.

New York Academy of Medicine, Section of Ophthalmology

Chairman: Dr. Mark J. Schoenberg, 1160 Park Ave., New York.
Secretary: Dr. Algernon B. Reese, 73 E. Seventy-First St., New York.
Time: 8:30 p. m., third Monday of every month from October to May, inclusive.

Omaha and Council Bluffs Ophthalmological and Oto-Laryngological Society

President: Dr. William P. Haney, 107 S. Seventeenth St., Omaha.
Vice President: Dr. L. G. Howard, 532 First Ave., Council Bluffs, Iowa.
Secretary-Treasurer: Dr. W. A. Cassidy, 1620 Medical Arts Bldg., Omaha.
Place: University Club, 1914 Harney St., Omaha. Time: 6 p. m., dinner; 7 p. m., program; third Wednesday of each month from October to May.

Pittsburgh Ophthalmological Society

President: Dr. Edward B. Heckel, Jenkins Arcade Bldg., Pittsburgh.
Secretary: Dr. George H. Shuman, Park Bldg., Pittsburgh.
Place: Pittsburgh Academy of Medicine Bldg. Time: Fourth Monday of each month, except June, July, August and September.

Pittsburgh Slit-Lamp Society

President: Dr. W. W. Blair, 121 University Pl., Pittsburgh.
Secretary: Dr. George H. Shuman, Park Bldg., Pittsburgh.
Place: 121 University Pl. Time: Second Monday evening of every month, except June, July, August and September.

Richmond Ophthalmological and Oto-Laryngological Society

President: Dr. William R. Weisiger, Medical Arts Bldg., Richmond, Va.
Secretary: Dr. R. W. Vaughan, Medical Arts Bldg., Richmond, Va.
Place: Westmoreland Club. Time: 6 p. m., second Monday of each month from October to May.

Rochester Eye, Ear, Nose and Throat Society

Chairman: Dr. E. S. Amsler, 53 S. Fitzhugh St., Rochester, N. Y.
Secretary-Treasurer: Dr. E. W. O'Brien, 5 N. Goodman St., Rochester, N. Y.
Place: Rochester Medical Association, 113 Prince St. Time: 8 p. m., third Monday of each month from October to May.

St. Louis Ophthalmic Society

President: Dr. Julius H. Gross, Carleton Bldg., St. Louis.
Secretary: Dr. Carl T. Eber, 1006 Carleton Bldg., St. Louis.
Place: Oscar Johnson Institute. Time: Clinical meeting 5:30 p. m., dinner and scientific meeting 6:30 p. m., fourth Friday of each month from October to April, inclusive, except December.

San Antonio Ophthalmolo-Oto-Laryngological Society

President: Dr. Scott C. Applewhite, 705 E. Houston St., San Antonio, Texas.
Secretary-Treasurer: Dr. E. D. Dumas, 425 Medical Arts Bldg., San Antonio.
Place: Bexar County Medical Library. Time: 8 p. m., first Tuesday of each month from October to May.

San Francisco County Medical Society, Section on Eye, Ear, Nose and Throat

Chairman: Dr. Robert C. Martin, 384 Post St., San Francisco.
Secretary: Dr. George N. Hosford, 490 Post St., San Francisco.
Place: Society's Building, 2180 Washington St., San Francisco.
Time: Third Tuesday of every month except May, June, July and December.

Shreveport Eye, Ear, Nose and Throat Society

President: Dr. J. L. Scales, Medical Arts Bldg., Shreveport, La.
Secretary-Treasurer: Dr. W. L. Atkins, 505 Medical Bldg., Shreveport, La.
Place: 1240 Texas Ave. Time: 7:30 p. m., first Monday of each month from October to June.

Spokane Academy of Ophthalmology and Oto-Laryngology

President: Dr. David Hartin, Old National Bank Bldg., Spokane, Wash.
Secretary: Dr. W. W. Henderson, Paulsen Medical and Dental Bldg., Spokane, Wash.
Place: Paulsen Medical and Dental Library. Time: 8 p. m., fourth Tuesday of each month except June, July and August.

Syracuse Eye, Ear, Nose and Throat Society

President: Dr. M. G. Brown, 713 E. Genesee St., Syracuse, N. Y.
Secretary-Treasurer: Dr. A. Harry Rubenstein, Medical Arts Bldg., Syracuse, N. Y.
Place: University Club. Time: Second Friday of each month except June, July and August.

Tulsa Academy of Ophthalmology and Otolaryngology

President: Dr. Roy Dunlap, 108 W. Sixth St., Tulsa, Okla.
Secretary-Treasurer: Dr. Marvin D. Henley, 108 W. Sixth St., Tulsa, Okla.
Place: Medical Arts Bldg. Time: Monthly.